ANALYSES OF GRAIN RESERVES, A PROCEEDINGS

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ABSTRACT

This document contains five papers concerning world grain reserves and six concerning national grain reserves. The papers were presented at a Conference on the Systems Analysis of Grain Reserves in Philadelphia, Pa., on April 1 and 2, 1976. These sessions were sponsored by the Operations Research Society of America (ORSA) and The Institute of Management Sciences (TIMS), as part of their joint national meetings. Any opinions, findings, and conclusions expressed are those of the authors and do not necessarily represent those of ORSA, TIMS, the National Science Foundation, or the U.S. Department of Agriculture.

Key words: Grain, grain reserves, grain storage, world food security, market stabilization, agricultural policy, systems analysis.

Washington, D.C. 20250 August 1976

FOREWORD

Widespread concern has developed over instability in food supplies and prices due to recent world production shortfalls, and the precipitous drawdown in grain stocks. Considerable attention has been focused on stabilization measures, particularly the use of grain reserves, as a means of dampening fluctuations in food supplies and prices.

A number of researchers have begun to use economic analysis, simulation, and optimization techniques to study policy questions related to grain reserves. Some of these questions are:

- What instabilities arise from lack of grain reserves and who is affected by them?

- How large should a grain reserve be?

- What price and/or quantity rules should be used to build up or release stocks?

- What will a reserve cost and who should bear the cost?

- Who gains and who loses from a buffer stock?

A conference, under the sponsorship of the Operations Research Society of America (ORSA) and The Institute of Management Sciences (TIMS), was organized to bring together many of the active researchers studying grain reserves. The conference was held at the ORSA-TIMS joint national meetings in Philadelphia, Pennsylvania, on April 1 and 2, 1976.

Two sessions were held, one dealing with world, and the other with national, grain reserves. This report is a proceedings of these sessions. Collectively, the papers presented suggest some of the major research directions in the area, rather than an exhaustive overview. They will add to the current dialogue on grain reserves, and will provide useful insights for both researchers and policymakers.

Some of the material presented is based upon research which has been financially supported by the Economic Research Service, U.S. Department of Agriculture (USDA), and the National Science Foundation. The National Science Foundation and USDA are jointly supporting this publication.

The views expressed in this volume are solely those of the authors, and do not represent the viewpoints or policies of ORSA, TIMS, USDA, or the National Science Foundation. No implied endorsement is intended by these four organizations.

The papers which follow deal with many aspects of grain reserves. Hathaway lays out a policy perspective to define the problems which an international grain reserve is designed to resolve. Brandow and R. Johnson point out implications of establishing a national reserve, and provide frameworks for policy analyses. The eight other papers present analytical approaches to world or national grain reserves.

The authors have used somewhat different methodologies in developing their analyses. Techniques include stochastic supply and demand analysis (Reutlinger, et. al., Cochrane, et. al., Walker, et. al., and Ericksen et. al.); single objective

(D.G. Johnson, et. al.) or multiobjective optimization (Eaton, et. al.); and systems dynamics (Brzozowski) or multimodel simulation (Levis, et. al.).

The authors use somewhat differing assumptions, yet most of the models are flexible enough to accommodate many alternative assumptions. Each paper examines a slightly different problem; thus, there is little duplication of research results.

Many important issues were not considered in sufficient detail by any of these papers. What would be the impact of climatic changes on prospects for a buffer stock? How should the Soviet Union be dealt with in a grain reserve system? What would be the nutritional implications of a reserve upon the poorest people in less developed nations? What is the impact on production response of the existence of grain reserves? What level of reserves can the private sector be expected to carry? These, and many other questions, need more research.

Readers should recognize that, due to severe length limitations, the papers in this volume are abbreviated presentations of more complete analyses that have been or are being published elsewhere by the analysts. Readers are encouraged to write directly to the authors to obtain the full reports of research methodologies and results.

At the Conference in Philadelphia, five reviewers commented in detail on these papers. These individuals were:

- Richard Goodman, vice president of the Continental Grain Company, 1001 Connecticut Avenue, N.W., Room #301, Washington, D.C.

- Emma Rothschild, writer, 333 Central Park West, New York, New York 10025

- Jimmye Hillman, professor of agricultural economics, The University of Arizona, Tuscon, Arizona 85721

- Dale Hathaway, director, Internationational Food Policy Research Institute, 1776 Massachusetts Avenue, N.W., Washington, D.C. 20036

- G.E. Brandow, professor of agricultural economics, The Pennsylvania State University, University Park, Pennsylvania 16802

Their remarks, the responses by those presenting papers, and the question and answer sessions with the general audience in Philadelphia were recorded and transcribed. Due to our interest in prompt publication of these papers, it was not possible to include these transcripts. A copy of the full transcript of the discussions after the paper presentations may be obtained by writing either of the compilers of this volume.

We wish to acknowledge the work of many individuals who aided in arranging the Conference and who offered their advice on the preparation of this proceedings.

DAVID J. EATON AND W. SCOTT STEELE, Cochairpersons
ORSA-TIMS Conference on Grain Reserves

CONTENTS

GRAIN STOCKS AND ECONOMIC STABILITY: A POLICY PERSPECTIVE

BY

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ABSTRACT

The role of supply and price stability for grains is examined in a policy context. The effects of stabilization upon production and "social risk" are examined. It is suggested that stabilization of supply is very important to developing countries and that a supply insurance program might be the least expensive way to achieve the desired policy objectives.

Since my assignment is to give a policy perspective on the grain reserve issues, I will start with a direct quotation from the announcement of this meeting. I do so because I believe it is misleading, if not incorrect as stated, and it lacks adequate policy perspective, which I wish to discuss.

> "Human beings require energy from food to live. Humankind's capacity to feed itself is related to many factors: population, climate, economic development, social mores, economic systems, techniques of food production, health status, and others. A grain reserve is not such a factor that influences whether nutritional needs outpace food supply--it is only a means to temporize. At best, a reserve can alleviate the impacts of an isolated disruption in production. At worst, a reserve may only postpone the eventual paying of the Malthusian piper."

My fundamental argument is that reserves, viewed in the broad policy perspective, are much more than a means to temporize (which in itself is not unimportant); they do constitute a major element in nearly all of the issues mentioned relating to mankind's ability to feed itself.

RESERVES AS A MEANS TO TEMPORIZE

Since temporizing is given as the only value of reserves, let us examine this as a value of reserves. Temporizing, the shifting of consumption from one time period to another, is generally analyzed in a framework of price changes which, in the case of food, arise largely from unstable output. A

great deal of theoretical discussion has attempted to prove that neither consumers' welfare nor producers' income is enhanced by price stability.1/ This implies that reasonable supply stability, which shifts consumption from one time period to another, also reduces rather than enhances consumer and producer welfare, and therefore, that one has to search elsewhere for the reasons for grain storage.

It would appear that static economic theory is inadequate in this situation as in so many others. It is inadequate simply because it is not possible to measure consumer surplus (or loss) for someone who starves to death in the year there is no grain to eat. It is not applicable for the millions who live at the subsistence level even in good years. In this regard, the peasant farmer is smarter than the economic theorist, since the former generally stores a family food supply in good years knowing that the money obtained from selling the surplus of good years will not buy enough food in bad years to keep his family alive. Of course, in some societies the grain may be stored as livestock rather than grain.

The points here are that 1) the use of standard theory to rationalize and determine the size of reserves is inadequate if not irrelevant,2/ and 2) another body of theory is more applicable, especially since I believe it is how policymakers can and should view grain storage. That theory is the theory of risk and insurance. As I turn to that element, I also wish to discuss other aspects of reserves.

RESERVES AND THE PRODUCTION AND AVAILABILITY OF FOOD

The opening quotation suggests that reserves have no effect upon the longer-run production and availability of food. This contradicts much of the long-accepted theory and fact regarding the economics of agricultural production.

First, the absence of reserves in a world of fluctuating production automatically means widely fluctuating grain prices, especially in countries where the price elasticity is low. One of the participants in this session, D. Gale Johnson [2], wrote a book many years ago which was to an earlier generation of graduate students a classic required reading. As far as I know, its theory is still valid, and its hypothesis has been varified by numerous

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1/ This case was first made by Frederick W. Waugh [7]. Unfortunately, not everyone read the article carefully, for Dr. Waugh (p. 613) stated, "this theorem is true only if the consumer can adjust his expenditure among the n periods in the way we have indicated." This obviously is not the case for poor people and food. The theorem was extended to producers by Walter Y. Oi [3, 4]. It was refuted by Paul Samuelson in [5, 6].

2/ I mean in this case the use of theory which measures consumer surplus or the area under indifference curves. I consider it inadequate, because it cannot measure the irreversible losses due to inadequate food supplies.

studies in both developed and developing country agriculture.

Johnson pointed out that risk and uncertainty reduced production efficiency in several ways. Risk of price changes lead to both internal and external capital rationing, thus resulting in a less than optimal combination of resource use and a shift of the supply curve to the left. In addition, the uncertainty arising from unstable prices makes it difficult for producers to plan their resource allocation, which also reduces the efficiency of resource allocation within firms and reduces specialization between farms, another source of potential production efficiency.3/

Dr. Johnson's book was written with U.S. agriculture in mind. But, the importance of risk and uncertainty for poor farmers in developing countries also has been shown to be important, given their low capital assets and the necessity to borrow in high-cost capital markets to adopt new technology and modern inputs such as fertilizer. Therefore, it follows that a reserve program which moderated the instability of grain prices (at profitable prices to producers) is an important element in speeding the adoption of new technology, encouraging the use of purchased inputs such as fertilizer and pesticides and, perhaps most important, to encourage a high rate of private investment in output-increasing items such as tube wells, minor irrigation, and land leveling. Thus, a grain price stabilization policy would appear to be a major element in any program to increase the growth rate and productivity in agriculture, and therefore, should be an important element in production policy.4/

The case is equally strong in economies where grain-fed poultry and livestock are important. The instability of grain prices is a major risk for poultry and grain-fed livestock producers. In the absence of reasonably stable prices, livestock producers will self-insure against this risk by requiring higher profit margins as a form of self-insurance. Thus, again grain price stability is an important factor in production efficiency.

In developing economies, reserve-induced price stability also may be an important factor affecting the market supply available from a given level of production. The prospects of shortages and price increases in an economy on the margin of subsistence increases the profitability of increased private stock-holding (commonly called hoarding) by farmers, individual consumers, not to mention the infamous middleman. Thus, when total supplies are short, there is a tendency for individuals throughout the system to increase private stocks and reduce market supplies, actions that amplify the magnitude of market price swings. Thus, lack of reserves to moderate price increases encourages private actions which are exactly the opposite of those which are needed in times of shortage.

Most policymakers concerned with food seek both to increase the food supply available to consumers and to avoid disaster. Unfortunately, I believe that too few policymakers understand and stress the role of stable

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3/ Samuelson makes this same point in his rejoiner, op. cit. [6].

4/ There are of course many other elements which influence the risk of producers, especially unstable weather.

prices and reserves in increasing the efficiency of food production and in making a larger portion of the food produced available in times of short supply. Economists sometimes contribute a limited vision of stocks and stabilization policies and have forgotten their potential contribution to production.

STOCKS AND POPULATION

Whereas the case for supply and price stabilization as an important element of production and distribution policy rests upon a solid theoretical base, the relation of stable food supply to improved health and nutrition does not, at least in the literature I have seen. However, I believe such a case can be made, and I shall attempt it.

It is asserted that when food supplies are very short in developing countries, the food intake of the children and women is reduced first. This results in a high incidence of child malnutrition and/or undernourishment in countries and for populations where the nutrition level is minimal in good years. Nutritionists are divided as to whether the physical and mental damage is irreversible, but there appears general agreement that malnourishment is a strong contributing factor to high infant mortality rates. The desire for male heirs, together with high infant mortality, often is cited as contributing to high birth rates in developing countries.

If we, as economists, accept that nutritionists, sociologists, and anthropologists can verify these hypotheses, then it logically follows that a stable and adequate minimum food supply can be a factor which will contribute to lower infant death rates and healthier and more productive adults. If birth rates decline as a result, then one can postulate a less rapidly growing, more productive population. Thus, without extending ourselves too much, it appears possible that a stable food supply, especially for those people on the margin of subsistence, could be a contributing factor to both family planning and to increased economic productivity.

THE MULTIPLE ROLE OF SUPPLY STABILITY

It would appear that a case varying from strong to plausible can be made that stabilization of grain supplies, especially in poor developing countries, must be a strong element in any policy to encourage the adoption of new technology, in encouraging the efficient use of output increasing inputs and capital investment and in population policy. These have little to do with temporizing, but all are involved in the desire of individual farmers and policymakers to avoid risks, especially those which will lead to irreversible and undesirable consequences. This brings me back to the theory of risk and insurance, with a suggestion that if reserves are viewed and treated in this fashion, a much more rational and less expensive grain reserve policy would be developed.5/

5/ The use of an insurance scheme is proposed in [1].

Food policy has two basic elements: 1) the provision of an adequate and improving food supply to consumers, and 2) the avoidance of economic, social, and eventually political disasters. These dual goals are neither inconsistent nor irrational, for they are the same objectives that underlie policies relating to energy and other basic goods without which an economy cannot function.

The basic nature of the disaster which the food policymaker, especially in a low-income developing country, wishes to avoid is fairly obvious. First, he wants to avoid the human misery and possible starvation that food shortages can create and which may lead to the ultimate disaster for a political leader--involuntary retirement from office and possibly from this earth. Second, the food policymaker wants to avoid the risk of a serious food-price induced inflation which can disrupt economic growth, drain foreign exchange urgently needed for development programs, and become a reoccurring initiator of a wage-price spiral which can only be controlled by monetary policies guaranteed to reduce economic growth and hurt the marginal members of the labor force the most. In addition to these general economic effects that occur in all countries, there are others which dominate poor developing economies which are largely agricultural. These consequences extend to actual famine, the widespread loss of farm capital in the form of animal power, the social and economic disruption of mass rural-urban migration, and the consequent long-term disruption of agricultural productivity.

There is neither time nor need to document here that grain shortages can have the disastrous effects I have briefly discussed. We have, over the past four years, seen these effects in varying degrees, ranging from the unpleasant inflation experienced by the United States as a result of sharp grain price increases, to the extreme inflation and the fall of governments in some of the less resilient developing economies. It should be enough to merely remind the knowledgeable observer of the recent past that the risks are real and that political leaders recognize their reality and want insurance against them.

If we accept the principle of risk aversion as a major reality in food policy, we should then examine the relative ability and/or willingness of certain types of countries to bear that risk, ways in which that risk can be reduced, and the alternative costs of reducing the risks. For this purpose, let me lump the combination of risks of inflation,[6] of actual starvation, of a major slowdown in economic growth rates, and of political upheaval into a general term "social risks" which has about the same content and meaning as social costs and benefits. The probability of incurring a given social risk also is a function of variation in supply.

6/ The FAO document, /_1_/ pp. 6-7 also makes the point that crop shortfalls are larger than above trend crops and that price elasticities rise during shortages. In this case the risk of shortfalls in grain supplies is not normally distributed and the case for insuring against them is stronger.

In a very poor country where the bulk of the population lives at or below the margin of healthy subsistence, where the grain supply is consumed directly, where the food price index is half or more of the cost of living index, and where 60-80 percent of consumer income is spent on food, the risks associated with a significant reduction in grain supplies and the associated price rises are very high. If the country has limited physical import capacity and internal food distribution system, the risks associated with internal production shortfalls are increased..

The social risks in the poor, low-income, agriculturally-based economy are increased by the fact that in such economies the marketable surplus is a function of the quantity above that which the farmer holds for his own family consumption and payment in kind to his various creditors. This means that production variations result in much greater variations in market supplies and prices; thus, a given shortfall increases the social risk of wage earners and is perceived by policymakers. This would also apply in years of ample supplies which would depress producer prices.7/

Conversely, in a wealthy grain exporting country where food is a lesser element in the cost of living, where much grain is fed to livestock, and where few, if any, are on the real margin of subsistence, the social risks of a decline in grain availability are much less.

Presumably, developed food importing countries fall somewhere in between in the "social risk" involved in grain supply variations, depending in part upon their income level, balance of payments position, and other factors.

It seems reasonable to assume that just as "social risk" may vary with conditions, the willingness of national policymakers to take risks may vary, just as does the willingness of individuals. Thus, countries which have the same inherent "social risk" might wish to have different levels of protection against such risks, just as individuals. And, as in the case of all insurance, the more risk borne by the insured or the lower the probability of exposure the lower the cost of their participation in the program. On the other hand, the very large or very wealthy often are self-insurers inasmuch as they can either afford to bear the entire risk or the premiums for insuring are so high that they outweigh the advantages of insurance.

Let us examine how such a principle might be applied to the grain reserve problem.8/ First, let us assume there is a supply insurance program for the very poor countries which are intermittently self-sufficient or chronically

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7/ Part of the social risk also is in low farm prices. This is especially noticeable in rich countries with democratic elections, but it also relates to long-run agricultural productivity mentioned earlier.

8/ The insurance example given in the FAO document, [1] pp. 23-29, assumes an insurance program in addition to an "optimum" stock program. My argument is that a reasonable insurance program would reduce the "optimum" world stock-hold to a lower level than the case of a single pooled stock.

deficit for shortfalls in production of more than 5 percent from a recent moving average of their consumption level.

On the other hand, let us assume that the policymakers in one or several developed countries decide that they can bear a "social risk" of a 10 or 15 percent decline in per capita consumption, especially in grains fed to livestock.

This then gives a basis for a supply insurance scheme which guarantees participating countries a supply necessary to fill the shortfall between their actual production and the insured portion of their recent consumption level. It would be possible to tie this supply insurance to a price guarantee in order to deal with foreign exchange problems, but to do so would prevent the use of prices to divert grain from one use to another, and it would make it relatively inexpensive to use commercial imports to achieve 100 percent supply insurance. Thus, the foreign exchange problem probably should be handled by a separate compensatory mechanism. In addition, since the foreign exchange portion of the problem is unique to poor developing countries, it should be confined to them.9/

There is a very obvious difference between the usual theory of insurance and insuring a grain supply. In the case of grain supply, the insurance has to include immediate availability to the physical product. Thus, either the insurance must be held as a physical quantity or some portion of the participants in the system must be willing to release their claim on a given quantity of the physical supply thus incurring a "social risk" of their own. In general, this risk, in the absence of physical stocks and with free trade, should be spread over all other importers and exporters, although the desire of every policymaker naturally is to reduce his country's risk, if necessary, at the expense of increasing that of others. Given this propensity to avoid risk, it would appear that some physical stock would be necessary to back up such an insurance scheme.

The actual physical quantities needed in a reserve system to insure the supply levels in the developing countries should be quite low, assuming that the developed market economies are willing and able to assume larger variations in consumption levels via their livestock industries. The FAO document /_1, p. 24_/ shows the maximum storage insurance payments in any year to be 5 million tons, but the calculations are made on a different basis. Different assumptions might produce higher figures, but they would be much lower than under most other plans. Thus, the stocks needed for the major developed countries to reduce their "social risks" to acceptable levels and still minimize the risks of poor developing countries would be rather small. This is especially true, since the probability of a serious crop failure in all poor developing countries in a single year is very low.

On the other hand, the principle of insurance is based upon a pooled risk of the probability of an undesirable event happening to a defined

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9/ To the extent that the probability of incurring losses is higher in poor countries than rich and the need for a higher level of coverage is obvious, the additional premium cost for such countries should be borne by other countries.

population. The probability is computed on the basis of independent events and can be calculated on the basis of experience. While unmarried male automobile drivers, aged 18-24, may have the approximately same probability of an accident from one year to the next, it is questionable whether such a calculation can be made for the probability of two consecutive bad crop years on the basis of historical data. Crop failures, however, are not independent events for each country, inasmuch as weather patterns tend to affect areas larger than single nations, especially in monsoon Asia, Sub-Sahara Africa, and the Great Plains of North America. While India, Bangladesh and Sri Lanka might have different "social risks" which are independent, they do not necessarily have independent probabilities of random reductions in domestic crop output. Thus, the size of physical stock needed would be based upon some assumptions which standard probability calculations do not provide.

Leaving aside these difficulties, let us examine how insurance principle might apply and how it influences the size and location of stocks. Let us assume that a country wants an insurance against shortfall of more than 8 percent of recent production. How much grain must they physically store and what other guarantees must their insurance include?

First, since physical consumption cannot be postponed, a country would need stocks in the country necessary to insure 95 percent of "normal" consumption until it was possible to import and distribute grain from the insurance pool. If this is backed by a guarantee of access to the quantity necessary to fill 95 percent of the rest of the shortfall between domestic production and normal consumption, the actual quantity needed in most countries is relatively small. If one assumes that it takes 60 days for internal distribution from outside supplies to begin, then the in-country stock required is one-sixth that required to self-insure for the same level of shortfall. It rises, of course, for countries with poor import and distribution facilities, but it is still much less than is needed in the country to cover the entire 95 percent of the maximum expected shortfall. What is happening at present, with no reserve policies, is that each country is trying to build the physical stocks required to self-insure for its entire shortfall. The result, if pursued, will be much larger total stocks than needed to operate an insurance system, since in essence each country with a stocks policy is attempting to self-insure for its own "social risk."

On the supplying side, the insurance merely involves an agreement of all exporting countries that they will provide exports of grain up to the amount that the importing countries want to insure for, regardless of their domestic supply in the exporting country. Since this would increase the "social risk" of the exporting countries, which they probably would want to reduce by carrying some stocks, such agreements would involve additional costs to them and should carry premium costs. These would be calculable, and who pays the insurance for poor countries could be separated from the other issues.

The insurance principle does not have to fix specific price bands for international trade as do stocks programs which have price stabilization as their objective. Different price bands are both desirable and acceptable in different countries, and some price changes are needed to divert grain from livestock to human consumption in years of very short crops.

Most of the stocks negotiations fail on the disagreement over the desired and/or acceptable price bands. An insurance scheme could allow these different preferences to operate and the costs for them assessed and paid.

Another advantage of the insurance approach is that the need for "emergency food aid" stocks can be eliminated by this system. A very poor, chronically food deficit country always needs supply insurance and balance of payments assistance, with the amount depending upon the harvest.

Ironically, while the United States has been opposing reserve stocks proposals to stabilize prices, it has, in fact, been selling supply insurance at a very low price to some developed countries. Basically, the "supply assurance" agreements with Japan, the USSR, Poland, Rumania, Israel, and Taiwan are different forms of supply insurance, and the only premium charged has been a guarantee to buy from the United States. This is a low premium for chronic food-deficit countries. Since these are wealthy countries, the lack of balance of payments insurance does not greatly increase their "social risk." Thus, the United States is allowing them to determine their desired price band without any premium. It is difficult to understand why the same principle cannot be applied to poor countries.

The size of the grain reserves needed to provide the supply insurance desired by deficit countries varies with the willingeness of the large exporting countries with high levels of grain consumption to increase their own "social risk" to insure a reduction in risk for the importing countries. If the rich developed countries are willing to increase their own "social risk" to insure the poor country's high "social risk," which I doubt, then no significant reserves would be needed. We have seen that a country like the USSR can bear the cost of its limited port capacity and lack of storage capacity by reducing its consumption drastically in 1975-76. Whether the "social risks" to the economy, the party, and the <u>former</u> Minister of Agriculture were tolerable is a matter of conjecture. Given their proposed large investment in grain storage facilities in the next five year plan, it appears the "social costs" were not acceptable, and they are embarking upon a large self-insurance program in addition to the low-cost insurance provided by the United States in the recent grain agreement.

It would seem clear that the application of this principle to all countries which wished to join could be made with much less difficulty than a traditional stocks program. The stocks needed to prevent unacceptable price fluctuations in the developed high-grain consuming countries would be much lower and less costly than a program of individual country self-insurance which is the essence of the "Boerma Plan" and the U.S. proposals. I would hope that some of the calculations of these costs and applications are made in the paper by Dr. Johnson which follows.

CONCLUSION

Grain reserves have an important element to play in encouraging efficient production, in contributing to a healthier and perhaps less rapidly growing population, and most importantly to the avoidance of economic, social, and

political disaster. To suggest that they merely temporize misses the major policy elements in a reserve policy which stabilizes world grain supplies and prices within tolerable limits.

I have suggested that these elements have a varying importance in different economies, and that a supply insurance program, which allows variation in the supply which is related to the economy's ability and willingness to bear the variations, would be the least expensive way to obtain the benefits from reduced supply and price variations. Physical stocks would be required under such a program, but the cost of bearing these stocks could be assessed and would not have to be borne entirely by exporters as was the situation in the 1960's.

ACKNOWLEDGEMENTS

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SHOULD DEVELOPING NATIONS CARRY GRAIN RESERVES? /1,2/

by

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ABSTRACT

This paper develops a method to simulate an investment in a grain reserve and calculate its efficiency, equity, trade, and stabilization impacts on a less developed nation. The method is applied to a hypothetical case - a normally 'self-sufficient country.' Such a country engages in limited importing when domestic harvests are poor and world grain prices are low. Exportation would occur given a bumper crop or high world prices.

The results suggest that an investment in buffer stocks is not likely to be profitable or capable of yielding a net positive economic efficiency benefit. Consumers will generally lose. However, if the government uses a subsidy program to maintain a minimal level of consumption by the poor, a reserve can result in substantial savings and thereby indirectly benefit low

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/1/ Footnotes are noted in brackets, / /, and are shown on the bottom of each page. References are denoted by numbers underlined and within parentheses (#), and are listed at the end of this paper in a separate section.

/2/ This paper is a much abridged version of (2).

income groups. While such a subsidy program would also benefit farmers, a buffer stock will reduce their potential gains.

One certain benefit of a grain reserve for a less developed country is the buffering effect of a stock upon certain accounts, such as the level of available grain supplies, domestic grain prices, and the balance of imports and exports. Trade as a policy option also stabilizes grain supplies and prices and has the comparative advantage of achieving large efficiency gains.

In summary, a decision by a less developed nation to carry buffer stocks may find limited justification on traditional economic grounds, such as profitability and economic efficiency. The strongest rationale for a reserve may rest, therefore, on its effect on a government's financial ability to secure minimally adequate consumption of grain for the entire population at all times and its incremental stabilization effects for prices, supplies and the balance of trade, which are not priced by the market.

OVERVIEW

For thirty years international organizations have sought to stabilize grain supplies available to less developed countries. In 1946 Sir John Boyd Orr, General Director of the U.N. Food and Agriculture Organization (FAO), proposed a World Grain Reserve. While this proposal was given rhetorical support over the following 25 years, no reserve was established. In 1973 Dr. Boerma, the past FAO Director General, suggested that a system of national buffer stocks be established. Each would be maintained by a country for its individual use but would be subject to international coordination.

In light of this proposed system of national reserves, it is relevant to ask whether a less developed country (LDC) would be wise to carry its own national buffer stock /3/. If it were true that a certain profit could be earned by buying grain in years of plenty and selling it in years of want, there would be no reason for international concern for buffer stocks. Individuals or companies would gladly come into the grain reserve business. The fact that grain traders are wary of buffer stock commitments should lead us to suspect, a priori, that a reserve might not be a profitable investment.

If a reserve was not profitable but was efficient /4/ as a public investment, there would be an incentive for a LDC to invest in a national

/3/ A buffer stock is a reserve to stabilize inter-year supplies of grain. Grain is saved during years of excellent domestic harvests or low international market prices for use in another year plagued by poor production. This inter-year stock is not the only purpose for which grain may be held. Nor is the existence of such a reserve a sufficient condition to guarantee that grain will be made available to the people who may need it.

/4/ Efficiency is defined as a net positive economic surplus or a net increment to national income (GNP).

buffer stock. The dearth of requests to international lending organizations for reserves lead us to suspect a priori that they may not be justified on traditional cost-benefit grounds.

However, profitability or efficiency are not the only raisons d'etre for a reserve; the investment decision will be made within a context of competing political interests. A farmer might accept a buffer stock if it increases and stabilizes his income over time. A consumer might evaluate a reserve by its ability to stabilize domestic supplies of grain. An economist might be concerned with maximizing long run net economic efficiency. A banker might prefer a reserve if it moderated instabilities in the country's balance of trade. A minister of finance would be vitally concerned with the fiscal implications of a buffer stock.

Each person has his view of how to evaluate the utility or performance of a buffer stock, using these or other criteria. An independent analyst should not bend to any one objective as a true goal. Analysis should show the implications of an investment decisions in terms of all criteria. This study adopts such a multi-criteria perspective to the evaluation of an LDC buffer stock investment.

The purpose of this study was to develop a methodology to evaluate the multiobjective implications of an LDC investment in grain reserves. This method is tested through application to a hypothetical LDC. Thus,the results presented herein should be viewed as being suggestive, presented to spur curiosity /5/. The particular application is based upon simple assumptions, related to but not being empirical data. In all model building efforts, the analyst is faced with a tradeoff problem between complexity and feasibility. A theoretician may be tempted to have the model contain every last variable which can help to explain past phenomena. As practitioners, we believe that it is best to initially represent the system simply, so as to reduce the cost and time of model construction and avoid dependence upon a data base which may be difficult if not impossible to obtain.

THE MODEL

The stochastic simulation model consists of five parts:

/5/ There are advantages and disadvantages to using a hypothetical rather than a real example to test the methodology. The disadvantage is obvious: the model is a second order abstraction of the real world. The advantages are two-fold. A hypothetical example is analagous to a controlled experiment, and may be used to uncover generalizations about central policy questions which an analysis of a particular real case might not provide. Also, by the use of many sets of hypothetical data, the analyst gains insight into which parameters are important in the system. Such understanding directs the efficient use of limited resources in the acquisition of data and improvements in the model.

(a) The generation of a large pseudo-random sample of sequentially ordered world and country grain production levels from their respective probability distributions.

(b) A world grain demand function, estimating world market price of grain for any level of aggregate world production.

(c) A country grain market model, yielding grain consumption, exports, imports, and dom stic grain price for each level of country production and world market price.

(d) A model for estimating benefits (gains) and costs (losses) from trade and storage to the economy, producers, consumers, and government accounts in each year.

(e) The generation of frequency distributions and summary statistics of quantities, prices, gains, losses, and other evaluative indices.

A full description of the model is available elsewhere (1). Here we can only highlight some of the essential features.

Stochastic Simulation

Stochastic simulation is a method of transforming a probability distribution of one or several variables into the probability distribution of one or many other variables. This model transforms world and LDC grain production distributions into distributions of the multiple criteria for evaluating trade or storage policies.

World and LDC grain production have been characterized as independent, normal distributions with no year-to-year correlation. These assumptions are made for convenience; different assumptions about the production processes can easily be accommodated.

Imagine that a grain reserve has an investment lifetime of 30 years. For a sequence of 30 observations of production, the model calculates the value of investment cycle criteria, such as the sum of net discounted efficiency benefits. Three hundred such 30-year investment cycles would generate a distribution of both annual and 30-year lifetime criteria variables. A simulation run consists of three hundred 30-year investment lifetimes, or a sample of 9000 years of production. /6/.

/6/ The number 9000 was chosen for convenience. This is quite a large sample of investment lifetimes; a larger sample does not produce significantly different results.

The country is assumed to be on average self-sufficient. This means that at the average levels of grain production in the country and the world, grain prices are in equilibrium. There would be no incentive to import or export grain.

If domestic production is below average or the world grain price is low enough, grain can be imported for current consumption. If there is an unusually good harvest or world prices are high enough, grain may be exported, but only out of current consumption. Grain is never imported simply to add to storage; nor will grain be released from storage for export /7/.

The country grain market model consists of a grain demand function, decision rules for trade, and decision rules for storage. This model estimates the domestic grain price and quantities consumed, imported or exported and put into or taken out of storage, given exogenous information on the level of domestic production and world price, a demand function and storage and trade rules.

World Prices

World production is transformed into a world market grain price through a pre-specified demand function. Different distributions of world market prices may be generated by varying either the probability distribution of world production or the shape of the demand function. /8/

Country Demand Function

Separate demand functions are specified for low income and high income consumers. Total country demand is the sum of the demand of the two population groups. The reason for specifying a separate demand function for the low income population is to permit an analysis of the effect of a minimum food maintenance policy of the government.

Trade Rules

In general, domestic grain price cannot exceed import price and cannot fall below the export price.

If the import price is below the domestic price, a sufficient quantity of grain is imported to equate domestic market price with the import price. When

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/7/ In a subsequent study, we intend to evaluate the case of a country which usually imports, rather than one which is normally self-sufficient. In the former case, imports will be permitted as additions for storage. Prices, rather than quantities, will trigger addition to or withdrawal from stocks.

/8/ For a full discussion of the world model, see (1).

the export price exceeds the domestic price, a sufficient quantity of grain is exported to equate the domestic price with the export price.

In the case of free trade, the difference between export and import prices and the world price is just the transaction costs - the expense of transportation. Trade is however constrained to never permit exports to reduce the country's consumption below a specified lower limit (Q_L) and never permit imports to increase the country's consumption beyond an upper limit (Q_U) /9/. In the case of restricted trade, an export and import tariff is introduced to widen the gap between export and import price and the world price.

Storage Rules

Imagine that storage is designed to stabilize grain consumption to within a pre-specified range, from Q_L to Q_U.

In a year of good production, when production (Q) is more than Q_U, the 'desired' amount of grain to be put into storage is $Q-Q_U$. The actual volume of grain stored depends upon the available vacant storage space. This vacant volume depends upon the reserve capacity and the inventory accummulation from prior years. Only after grain is stored can exports take place. Storage takes precedence over export.

Grain harvest is considered poor when production, Q, is below Q_L. The desired amount of grain to be released from storage is Q_L-Q. If grain can be imported at a lower price than the domestic price corresponding to Q, grain is imported. The actual amount of grain withdrawn from storage cannot exceed the amount of grain in inventory.

ESTIMATING GAINS AND LOSSES

The model can calculate the value of pecuniary indices of gains and losses from trade and storage. These criteria are profitability, gross and net economic benefits, producer benefits, consumer benefits, and subsidy savings.

Producer Benefits

The country's farmers gain when grain is exported or put into storage. Their gain is measured by multiplying domestic production by the difference between the price without and with trade and/or storage. The country's farmers always lose when grain is imported or taken out of storage. The loss is measured by multiplying domestic production by the difference between the price without and with trade and/or storage.

/9/ This rule may also be stated in price terms. Trade may be constrained to never permit exports to drive domestic price above a specified upper limit or to allow imports to push prices below a lower limit.

Consumer Benefits

Consumers always lose when grain is withdrawn from the market for export and/or storage. Their loss is measured by multiplying the average consumption (without and with exports and/or storage) by the price change. When the quantity of domestic grain production is supplemented with imports and/or grain out of storage, consumers always gain. Their gain is measured by multiplying average consumption (without and with imports or grain from storage) by the difference in price.

An exception to the above stated rule occurs when trade and/or storage are superimposed on a policy whereby the government provides a subsidy to insure some lower limit on consumption by the poor. In this case, the poor do not gain financially from a price reduction due to imports or release of grain from storage. The "consumer gain" instead accrues to the government in the form of savings on subsidy payments /10/.

Storage Authority's Gains

The storage authority incurs a cost when grain is put into storage and receives revenue when grain is sold out of storage. The cost is assessed by multiplying the amount of grain stored by the market price (after trade and storage). The revenue is the quantity of grain sold out of storage times the market price (after trade and storage). Our use of price after trade and storage implies that the storage authority is not a privileged buyer or seller; i.e., that its intentions are public knowledge.

Subsidy Savings

A subsidy operates by providing grain to low income consumers at a specified price level even when that level is exceeded by the market price. When a subsidy program is operative, the government gains from trade and/or

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/10/ The reader recognizes that gains and losses discussed here are purely pecuniary - those measured in the market. We accept the general criticism of static economic theory voiced by Dale Hathaway in the previous paper given at the Conference, "Grain Stocks and Economic Stability: A Policy Perspective":

... "It would appear that static economic theory is inadequate in this situation as in so many others. It is inadequate simply because it is not possible to measure consumer surplus (or loss) for someone who starves to death in the year that there is no grain to eat."

Dr. Hathaway further notes several effects of grain shortages not captured by markets:

"...actual famine, the widespread loss of farm capital in the form of animal power, the social and economic disruption of mass rural-urban migration, and the consequent long-term disruption of agricultural productivity."

storage if the market price is above the specified level. The savings are calculated by multiplying the volume of grain provided to the poor by the price difference (before and after trade and/or storage).

Economic Benefits

Gross economic benefit is the sum of all of the above gains or losses. It is the combined consumer and producer surplus obtained from allowing trade and storage, minus variable storage cost including interest on the value of inventories.

GENERATION OF SUMMARY STATISTICS

Imagine that quantities, prices, and gain/loss indices resulting from trade and storage have been calculated for each year of 300 thirty year investment cycles. From this sample of 9000 years and 300 investments, it is possible to calculate the frequency distributions and summary statistics (e.g., expected value and standard deviation) of many indices. Table 1 is a list of the output variables from the simulation and the formats of that output. The notation "B/C" stands for benefits or costs.

TABLE 1 : SUMMARY OUTPUT FROM SIMULATION MODEL

Variable	Frequency Distribution	Expected Value	Standard Deviation
world price	x	x	x
domestic price	x	x	x
balance of trade	x	x	x
domestic consumption	x	x	x
subsidy for poor	x	x	x
grain imports		x	x
grain exports		x	x
rate of storage utilization		x	x
economic B/C from trade		x	x
economic B/C from storage		x	x
producer B/C from trade		x	x
producer B/C from storage		x	x
consumer B/C from trade		x	x
consumer B/C from storage		x	x
government revenue from tariff		x	x
storage authority B/C from storage		x	x

THE BASE CASE

A set of model parameters was adopted as a 'base case' to study the implications of an investment by a LDC in a buffer stock. The assumptions of the base case are listed in Table 2 and described in detail elsewhere (2). Three hundred investment cycles, each of 30 years length, were simulated for six buffer stock capacities - 0, 3, 6, 9, 12, and 24 million metric tons (MMT).

Table 2: PARAMETER VALUES ASSUMED FOR BASE CASE

Item	Description	Specification
Production	World and country production are independent of each other, of storage, and of trade.	
World production (Q)	Normal independent stochastic process (N)	$Q \sim N(350, 14)$
World price (P)	Kinked linear demand function (yields a skewed frequency distribution of price)	$P = 541.0 - 1.19 * Q$ /$Q > 350$ MMT (million metric tons)/ $P = 1375.0 - 3.57 * Q$ /$Q < 350$ MMT/
Country production (Q_c)	Normal independent stochastic process	$Q_c \sim N(110,7)$
Country price (P_c)	Kinked linear demand function, interpreted to arise from government subsidy policy to maintain consumption of poor at 55 MMT	$P_c = 541.0 - 3.787 * Q_c$ /$Q_c > 110.0$ MMT $P_c = 1375.0 - 11.363 * Q_c$ /$Q_c < 110.0$ MMT/
Trade policy	Limited trade, constrained by tariffs	Transportation charge: ± $10/MT Tariff (import and export) charges: ± $25/MT Import = 0 if Q_c ± storage > 112 MMT Export = 0 if Q_c ± storage < 108 MMT
Storage policy	Domestic production triggers storage acquisition	if Q_c > 112 MMT, store if Q_c < 108 MMT, release
Storage costs		Loading/unloading handling costs: $2/MT Storage capacity costs - $100/T capacity Interest rate: 8%
Investment cycles, (sample size)	Analysis based on many simulated years of grain market operation	300 investment cycles, each of 30 years length
Buffer stock capacity	Alternate capacity sizes possible	0, 3, 6, 9, 12 and 24 MMT capacities

BASE CASE RESULTS

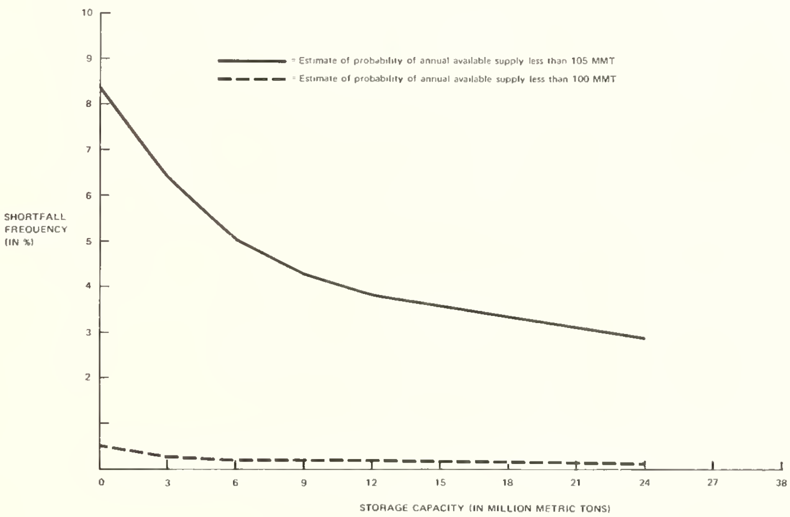
Stabilization Effects

Figure 1 is a graph of storage capacity versus the frequency of serious shortfalls, a surrogate for stability of grain supplies. Two shortfall levels are denoted, grain available for consumption below 100 MMT (dashed line) and below 105 MMT (continuous line).

A national buffer stock does stabilize grain supplies, according to the results in Figure 1. There is a tradeoff between stability and reserve size, in that greater stability can only be purchased by adding to reserve capacity

Each incremental unit of stability is more costly than the previous unit, in terms of the needed capacity additions. Following the continuous line in Figure 1, the first 3 MMT of storage capacity reduces shortfall frequency by two percent. However, moving from 9 to 12 MMT **capacity** is less cost effective - shortfall frequency falls by only 0.5 percent. The hatched line shows an apparent limit to the elimination of instability. Even at large buffer stock capacities, there exists a chance that serious shortfalls in grain supplies may occur.

Figure 1: EFFECT OF STORAGE ON THE RELATIVE FREQUENCY OF SERIOUS SUPPLY SHORTFALLS



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Another surrogate for stability is the size of the standard deviation of supplies over the 9000 sample years at each buffer stock capacity. In Table 3, we observe that this standard deviation is reduced as capacity is increased. The stabilization effect exhibits decreasing marginal returns to increments in storage capacity.

A grain reserve stabilizes not only supplies, but also national market price, the balance of foreign trade, and the level of subsidy payments by the government to poor consumers. For each of these variables, an increase in stock size implies a buffering of the natural fluctuations, as shown by the standard deviation of the variables in Table 3. Storage capacity increases display decreasing incremental stabilization effects.

Table 3: MEAN VALUES AND STANDARD DEVIATIONS OF GRAIN CONSUMPTION, GRAIN PRICE, BALANCE OF TRADE SUBSIDY PAYMENTS

	Storage Capacity (million tons)				
	0	3	6	9	12
Grain consumption (million ton)					
Average	110	110	110	110	110
(S.D.)	(4.5)	(4.0)	(3.7)	(3.5)	(3.3)
Grain Price ($ million)					
Average	137	136	136	135	135
(S.D.)	(31)	(28)	(26)	(24)	(3.3)
Balance of Trade ($ million)					
Average	22.6	26.4	26.2	24.5	22
(S.D.)	(747)	(668)	(617)	(581)	(553)
Subsidy Payments ($ million)					
Average					
(S.D.)	(1301)	(1184)	(1094)	(1031)	(990)

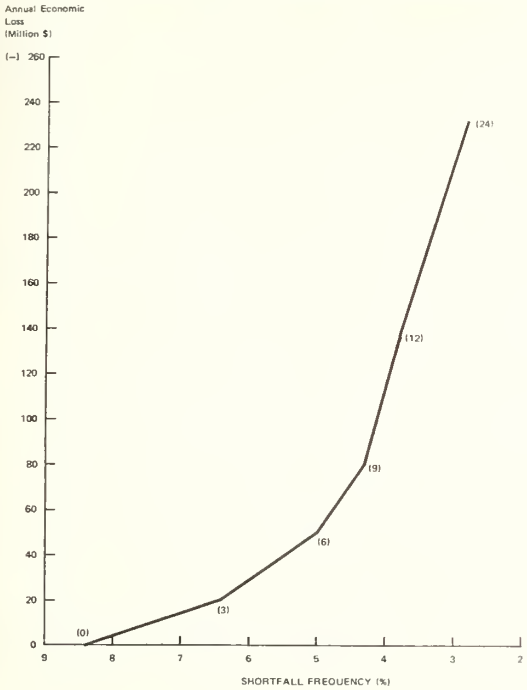
Efficiency and Distribution Considerations

Should a less developed country carry a national grain reserve? The traditional method to valuate such a question is whether the investment generates benefits which exceed the resource costs, and thus produces a net positive economic surplus. Figure 2 is a graph of the expected annual economic loss, on the vertical axis, versus an index of supply stability. This index, the shortfall frequency, is associated with storage capacity sizes, shown in parenthesis along the curve. Each new increment of supply stabilization is more expensive than the last, in terms of net economic losses to the economy. The first half percent of increased stability (8.5 - 7.9%) costs $5 million dollars in incremental economic losses. A later increment of approximately the same size (4.3 - 3.8%) costs $36 million in annual marginal losses.

If a buffer stock cannot be justified on efficiency grounds, is such a stock nevertheless advantageous in terms of its effect upon the distribution of benefits between interest groups? Figure 3 shows the distribution of gains and losses between farmers, consumers, and the aggregate government account.

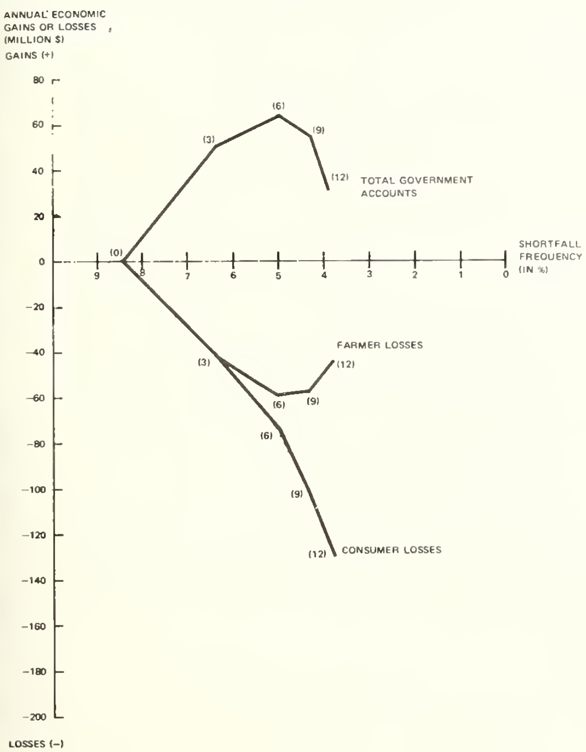
We observe that both farmers and consumers lose and the government seems to gain for awhile. Any reserve implies a financial loss to consumers, and there are increasing marginal losses associated with any increment of different. Farmers initially lose from a reserve, but these losses 'bottom out.' Indeed, farmers make marginal gains at higher versus lower capacities. The reason for this shift of fortune is that larger reserve size implies larger stocks and long half-lives of grain in storage. While a farmer's gain from

Figure 2: ANNUAL ECONOMIC LOSS AND SUPPLY STABILIZATION



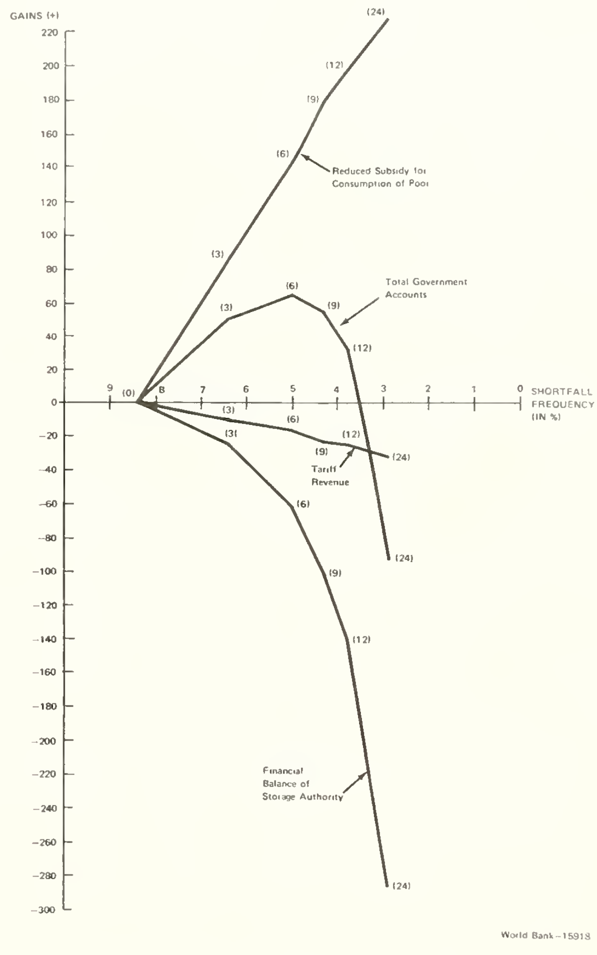
NOTES: 1. Shortfall frequency refers to annual supply being less than 105 MMT.
2. Numbers in parenthesis are the corresponding storage capacities.

Figure 3: SUPPLY STABILIZATION AND THE DISTRIBUTION OF ECONOMIC GAINS AND LOSSES



NOTE. Numbers in parentheses are corresponding storage capacities.

Figure 4: GOVERNMENT ACCOUNTS: ANNUAL GAINS AND LOSSES



NOTE Numbers in parenthesis are the corresponding storage capacities.

selling to the reserve increases, the discounted loss from buffer stock market sales is reduced as grain is withheld for a long time from the market.

The aggregate government account shown in Figure 3 seems to rise and then fall as storage levels increase. The reasons are shown in Figure 4, which disaggregates the government account into three components. There is a loss in tax revenue to the government due to reduced imports and exports as a consequence of storage operations and there is a direct loss from operating the buffer stock scheme. The initial net gain in the government account is due to large savings on subsidies for maintaining the consumption of the poor. Government accounts eventually fall because the rate of increasing losses due to reserve operations and tariff reductions is greater than the rate of increased savings in subsidy payments.

Summary of Base Case Results

The buffer stock investment is neither profitable nor efficient to the economy. However, on fiscal grounds, a modest buffer stock is attractive. Without a buffer stock, the expected cost to the government of subsidy payments to maintain consumption of the poor would be $1000 million. Tax revenues from tariffs on trade would be $70 million, yielding a net cost of $930 million. With a 6 MMT capacity buffer stock, the expected annual subsidy payments are reduced to $860 million, tariff revenue falls to $55 million, and the reserve costs $60 million to operate. Hence, the combined outlay for subsidies and buffer stock operations minus tariff revenues is $865 million.

Neither farmers nor consumers gain financially from the operation of the buffer stock. However, these conclusions must be carefully interpreted in light of the model's distinction between the demands of poor and other consumers.

Recall that government policy is to maintain the food grain consumption of the poor through price subsidies. While the poor consumer gains nothing directly from the lowering of prices when stocks are released, he may benefit indirectly. A grain reserve reduces the fiscal burden of the food maintenance policy to the government, and therefore provides an incentive to the implementation of the policy.

The farmer's lost revenue is in part a windfall gain arising from the government's policy to augment the demand of the poor consumer when prices rise above his means to purchase sufficient nutrition. Hence the fiscal savings to the government in operating the food consumption maintenance policy is also in the farmer's interest.

The stabilization effect of a reserve upon consumption, prices, government accounts, and the balance of payments is positive but not very large. However, the benefits from stability are indirect, are not measured by the market, and are difficult to quantify.

There are many obvious limits to the generalization of these results. The base case is predicated on many specific assumptions about production, trade, storage, and consumption processes. A government policy to subsidize

the consumption of the poor exists. Further, the results reported above are the expected value of annual benefits and costs. Thus a sequence of years could occur even with this base case where a reserve could be justified in traditional efficiency terms.

A second stage of analysis is to see how the conclusions are modified by changing the initial set of assumptions. A section of sensitivity analysis will explore the implications of changes in the parameters associated with world production, national production, and world demand. A section of policy analysis will examine how the assumptions relating to international trade, storage and release rules, and subsidies influence the results.

SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis section is to explore how changes in parameters associated with world production, country production, and world demand influence the results. Five simulation exercises were completed, each of which held all assumptions constant with those of the base case, save with respect to one 'supply' or 'demand' parameter. Two runs explored the effects of more or less stable world prices which were generated by decreasing (from 14 MMT to 7 MMT) or increasing (14 MMT to 21 MMT) the standard deviation of world production, respectively. Two sets of simulations were run for decreased (7 MMT to 3 MMT) and increased (7 MMT to 11 MMT) country standard deviation of production. A final set of simulations considered the implications of more stable world prices generated through more elastic world demand. Each set of simulations included storage capacities at 0, 3, 6, 9, and 12 MMT capacity.

Space limitations preclude complete discussion of these sensitivity analyses in this paper; they are discussed in detail elsewhere (2).

SENSITIVITY ANALYSIS - RESULTS

Stabilization Effects

More stable world prices, world production, or country production all result in a reduced chance of shortfall of grain supplies. The marginal stabilization impact of a reserve upon supply changes little from the base case, but drops in absolute terms. Since natural fluctuations are reduced, the buffering effect of storage is less noticeable.

Less stable world prices, world production, or country production lead to greater natural fluctuations in supplies. While the relative stabilization effects of storage upon supplies are roughly the same as for the base case, the absolute drop in the frequency of serious shortfalls is greater. Greater natural variability in supplies make the buffering effects of a reserve more evident.

Efficiency and Distribution Effects

The conclusion of the basic case that an investment in grain reserves is probably both unprofitable and inefficient remains robust. In all cases except for minute reserve investment (less than 0.01 MMT capacity), the net economic benefit due to stocks is negative. The income distribution effects of a reserve also seem stable over this range of sensitivity analyses.

POLICY ANALYSIS

The purpose of the policy analysis is to study how changes in LDC storage, trade, or subsidy policies affect the evaluation of a buffer stock investment. Five sets of simulations were run with a single policy change and all other base case assumptions held constant. Each policy shift was evaluated with 0, 3, 6, 9, and 12 MMT reserve capacities, and the marginal changes in the values of the multiple evaluative criteria were calculated.

Two sets of runs explored either eliminating or freeing trade. The base case assumed free trade limited by a moderate import and export tariff ($25/MT). Run P.1 looked at the effects of no trade, enforced by a tariff of $300/MT on imports and exports. Run P.2 investigated the relaxation of trade by eliminating tariffs altogether.

Two sets of runs examined alternate storage rules. In the basic case, storage was triggered if production exceeded 112 MMT and release occurred if production fell below 108 MMT. Run P.3 used a wider trigger band, 107 to 113 MMT. Run P.4 looked at the effects of more storage activity produced by storage and release rules of 111 and 109 MMT, respectively.

A fifth policy analysis, P.5, eliminated the government policy of subsidizing the consumption of the poor.

POLICY ANALYSIS - RESULTS

Space limitations preclude a detailed presentation of the results of the policy analyses; this information is available elsewhere (2).

The variation of storage operating rules in Runs P.3 and P.4 produces stabilization, efficiency, and income distribution results which are not significantly different from those of the basic case.

The elimination of the subsidy policy does have significant consequences. These results are discussed in a later section of this paper.

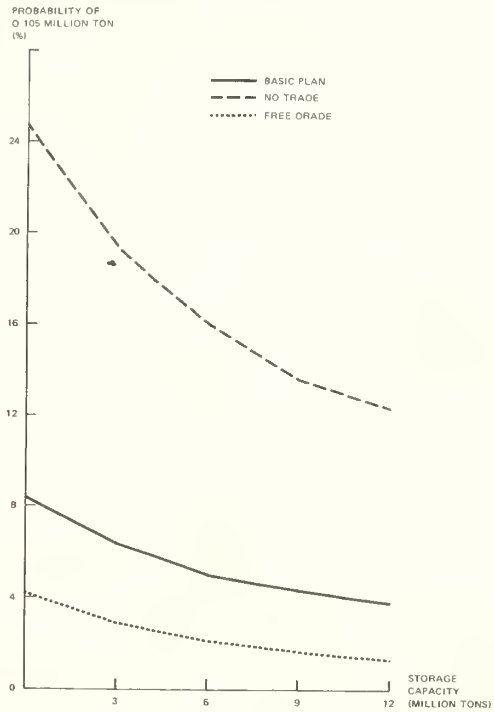
There are some interesting marginal effects of alternate stock levels under trade policies P.1 and P.2. These trade policy results are described in the following 3 subsections.

Stabilization Effects under Trade Policies

Figure 5 is a graph of frequency of significant shortfall in grain supplies ($Q \leq 105$ MMT) versus storage capacity for three alternate trade policies. The stability of grain supplues, denoted by the shortfall frequency, is related both to the volume of storage and to the trade policy. In all three cases - the base case, no trade, and free trade - an increase in stock capacity results in a decrease in the frequency of supply shortfalls.

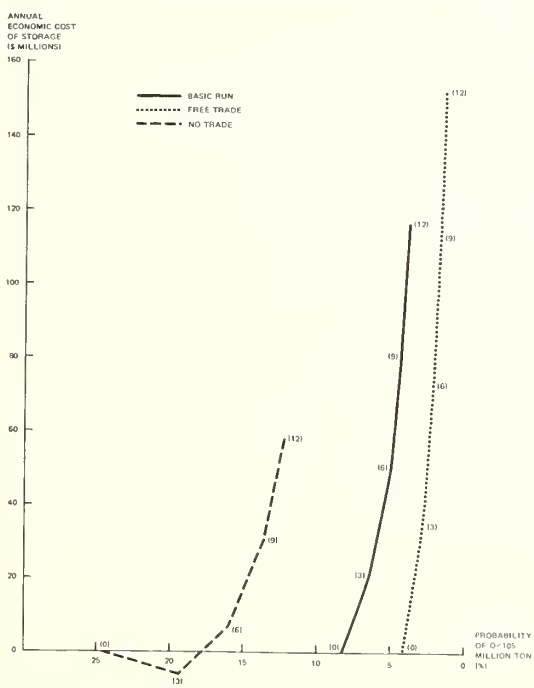
Of interest is the result that the freedom of trade is a significant determinant of the frequency of shortfall. Under more restrictive tariff conditions, there is a greater chance of shortfall. Trade is clearly an effective tool to stabilize grain supplies. The arginal stabilization effect of a buffer stock is greatest if no trade is permitted and least under a free trade policy, in both relative and absolute terms.

Figure 5: RELATIVE FREQUENCY OF SERIOUS SUPPLY SHORTFALL AND STORAGE CAPACITY WITH ALTERNATE TRADE POLICIES



NOTE Frequency of supply less than 105 MMT (%)

Figure 6: ECONOMIC COST AND PRICE STABILIZATION WITH ALTERNATE TRADE POLICIES



NOTE Frequency of annual supply less than 105 MMT (%)

Efficiency Effects Under Trade Policies

A buffer stock investment tends to yield a negative net economic benefit and be an inefficient investment regardless of the trade policy, as shown in Figure 6. Under both the base case and free trade, all stock capacities reduce GNP.

When trade is not permitted, a small reserve may be justified in cost benefit terms (less than 5 MMT). Any incremental investment beyond that point quickly yields net economic losses. When trade is not allowed, substantial profits may be earned by buying when prices are low and selling in a year of shortfall. However, these profits are inadequate to offset the fixed costs of even an intermediate-sized (6 MMT) grain reserve.

Income Distribution Under Trade Policies

Consumers tend to lose from a reserve, as shown in the top portion of Figure 7. Under either no trade or restricted trade (base case), every added increment of storage hurts consumers. They gain from a small buffer stock under a free trade policy, but lose as the size of the reserve increases.

Farmers lose from the existence of a buffer stock in a pattern shown in the bottom of Figure 7, whether there is free trade, restricted trade, or no trade. The first increments of storage capacity always do pecuniary damage to farmers. At higher capacity levels the losses tend to 'bottom.' Marginal gains do accrue to farmers in later increments of capacity (9 to 12 MMT).

Government accounts behave in a consistent way under all three trade polccies, as shown in Figure 8. There is an initial gain from reserve operations, followed by a 'topping off' of gains and eventual incremental losses at high capacity levels. The gains to the government are entirely due to savings on subsidy payments. These savings are very large when trade is eliminated as an option for stabilizing prices.

COMPARISON OF POLICIES: STORAGE VS. TRADE VS. SUBSIDY

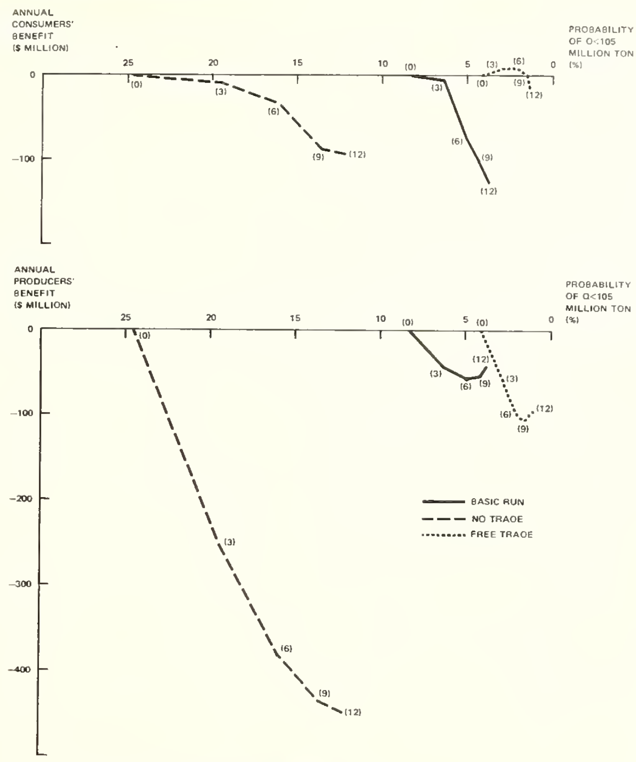
Throughout this paper, our focus has been upon the incremental effects of a grain reserve investment - what are they and how are they affected by different assumptions. In the previous section, we noted that storage and trade policies seem to be inter-related. This suggests 'the next higher order question':

- What is the total effect of each or any combination of the three policy options, trade, storage, and the subsidy for maintenance of the consumption of the poor?

This question will be explored in this final section. The focus is upon which policy option or options performs best to achieve a given social objective or set of many such objectives. These results are shown in Figures 9 through 18 and are discussed below.

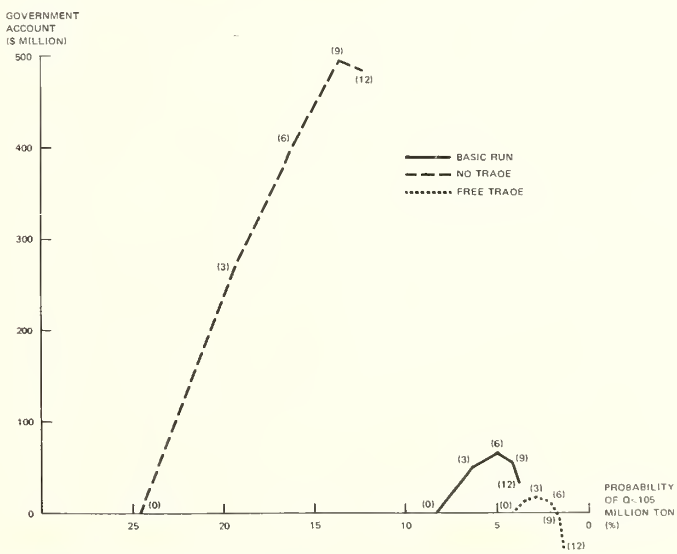
Reserve policies are either no reserve or one of 6 MMT capacity. Trade policies are either no trade or free trade. Free trade is really a case of no tariffs limiting trade; restrictions on trade still exist so that imports do not drive consumption above 112 MMT and export cannot occur when supplies fall below 108 MMT. There either is a subsidy to maintain the consumption of the poor by holding down the price they must pay to $125/MT or no such policy is enforced. There are eight combinations of storage, trade,and subsidy policies.

Figure 7: ANNUAL CONSUMER AND PRODUCER LOSSES AND SUPPLY STABILIZATION WITH ALTERNATE TRADE POLICIES



NOTE: Numbers in parentheses are the corresponding storage capacities.

Figure 8: SUPPLY STABILIZATION AND GOVERNMENT ACCOUNTS WITH DIFFERENT TRADE POLICIES



NOTE Numbers in parentheses are the corresponding storage capacities.

Stabilization Results

Trade, storage, and subsidy policies all affect the stability of supplies, prices, balance of trade, and subsidy payments. The adoption of a subsidy policy may either slightly stabilize (grain supplies) or de-stabilize (prices and balance of trade) accounts, as shown in Figures 9 through 11. Both trade and storage tend to reduce fluctuations in all four accounts. The addition of trade alone (without storage) is always superior to the option of storage alone (without trade) in terms of the increment of stability. Storage and trade together reduce variability more than either factor alone. In short, storage may be helpful to reduce uncertainty concerning supplies and prices. However, trade is better than storage for achieving stability.

Efficiency Results

Subsidy payments are very costly in terms of net economic losses, as shown in Figure 13. Since the economic efficiency criterion attaches no value to maintenance of consumption by the poor, this result is not surprising.

Free trade produces a substantial economic surplus, as might be predicted from traditional economic theory. However, it is noteworthy that the economic surplus produced by the combination of free trade and a subsidy policy is only slightly less than the surplus from free trade without subsidy payments.

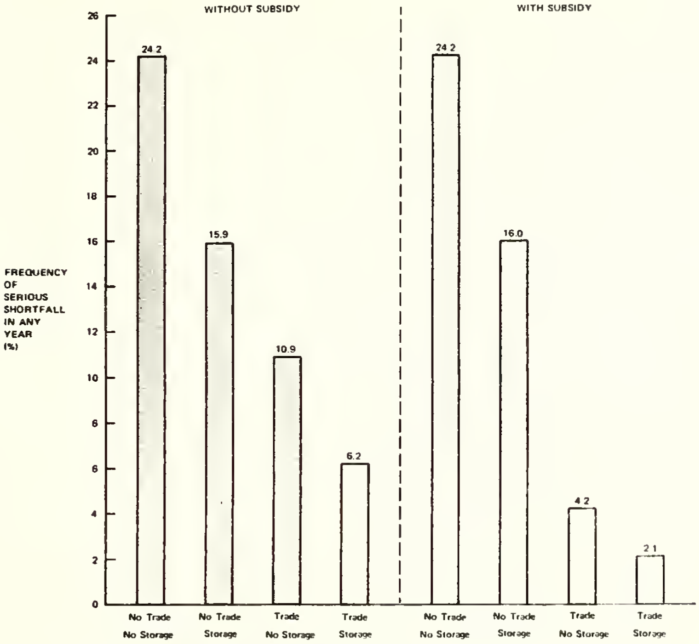
These results clearly demonstrate that freeing trade may be particularly important for a country which is serious about maintaining food consumption of the poor. The expected marginal gain from trade for a country with a subsidy policy was $700 million per year /312 minus (-388)/. This gain in net economic benefits is more than double the gain for a country without a subsidy policy ($325 million).

The magnitude of the net economic benefits or losses that accrue from trade and/or subsidy policies dwarf the incremental net economic losses due to storage policies.

Distribution Results

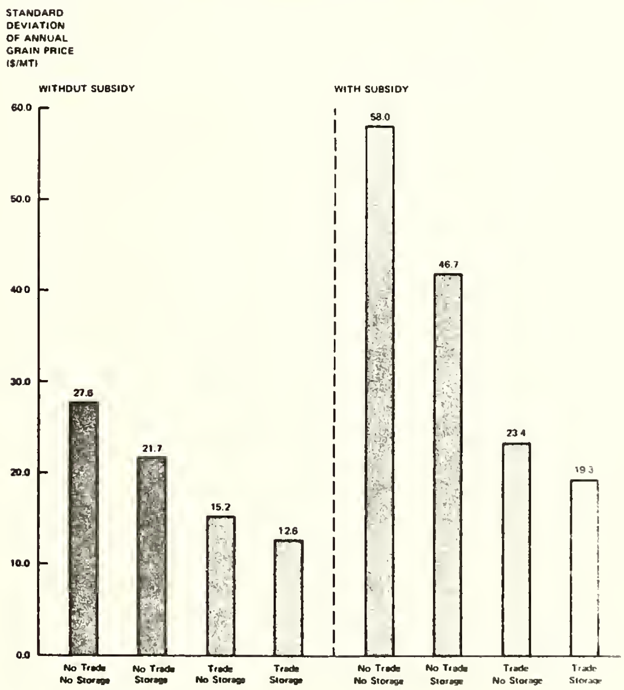
Farmer's income, in the absence of a subsidy policy, is increased by storage or trade alone (Figure 14). Trade alone is better for farmer's income than storage alone. Trade and storage together leave the farmer slightly worse off than under trade alone. The addition of a government subsidy program profoundly improves farmer's income. This policy alone produces double the increase in farmer's income versus trade and more than order of magnitude increase above storage alone. Storage and trade policies alone or together reduce farmer's income if a subsidy program exists; what government policy gave, it now takes away. Farmers will clearly favor a subsidy program but be cool to either increased trade or storage should such a subsidy program exist.

Figure 9: HOW ALTERNATE POLICIES AFFECT FREQUENCY OF SHORTFALLS OF GRAIN AVAILABLE FOR CONSUMPTION



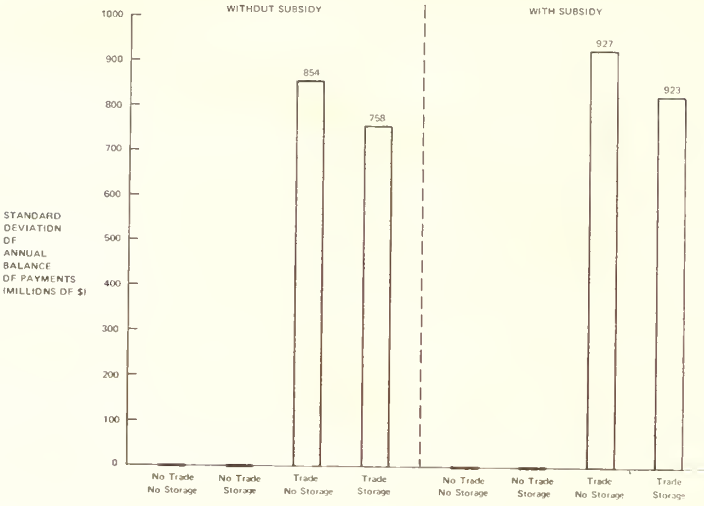
NOTE: Values of all indices for 6 MMT storage.
Shortfall defined as annual supply available being less than 105 MMT

Figure 10: HOW ALTERNATE POLICIES AFFECT PRICE VARIABILITY



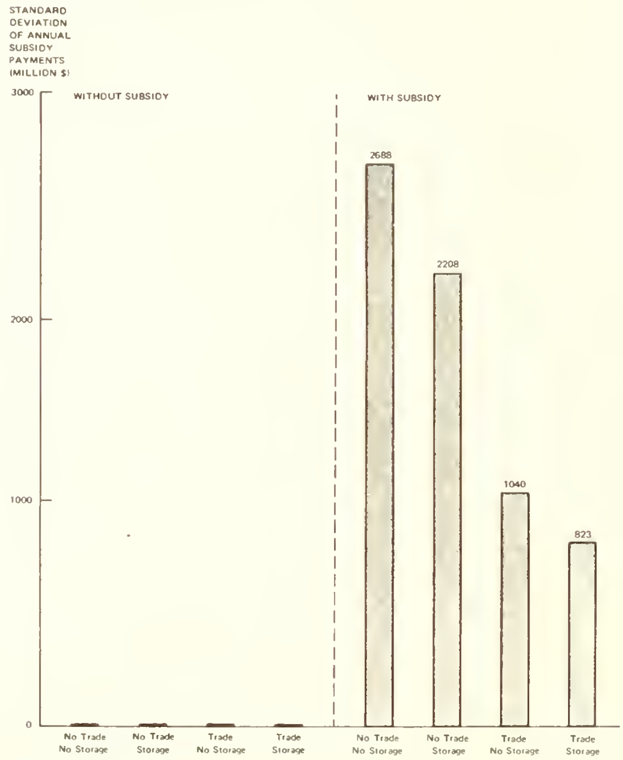
NOTE: Value of all indices for 6 MMT storage capacity.

Figure 11: HOW ALTERNATE POLICIES AFFECT VARIABILITY OF BALANCE OF PAYMENTS



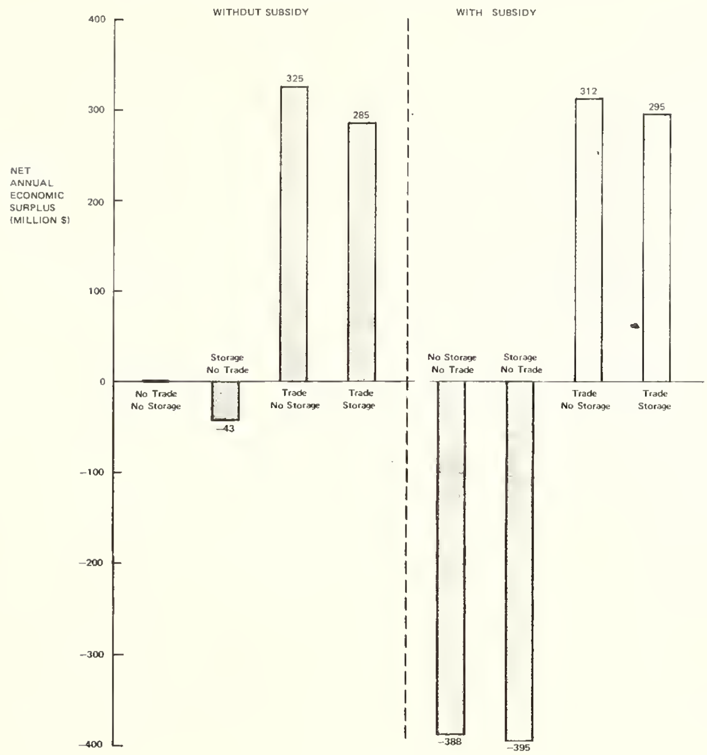
NOTE Values are calculated for 6 MMT storage capacity

Figure 12: HOW ALTERNATE POLICIES AFFECT VARIABILITY OF GOVERNMENT SUBSIDY PAYMENTS



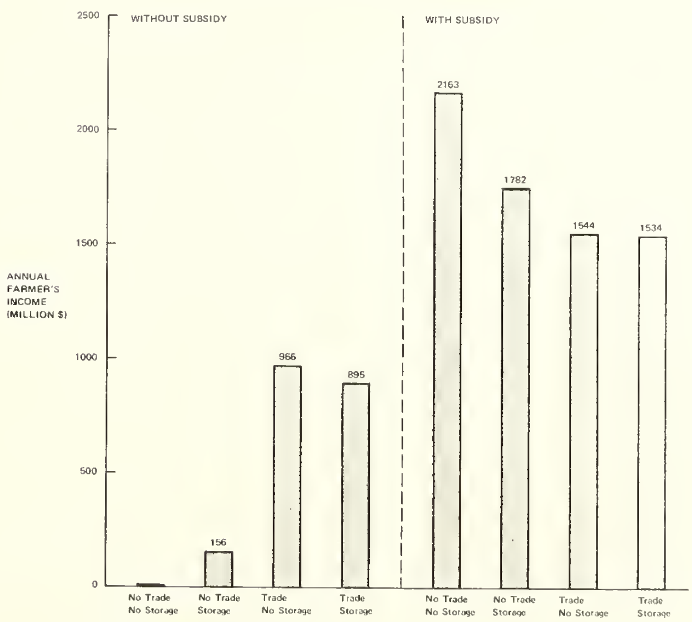
NOTE All storage results calculated for 6 MMT capacity

Figure 13: HOW ALTERNATE POLICIES AFFECT THE NET ECONOMIC SURPLUS



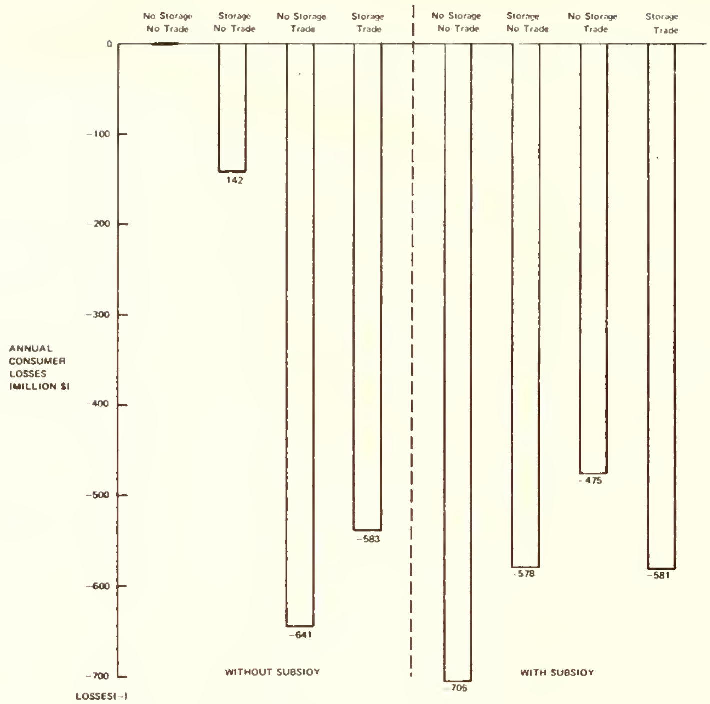
NOTE: All storage results calculated with 6 MMT storage

Figure 14: HOW ALTERNATE POLICIES AFFECT FARMER'S INCOME



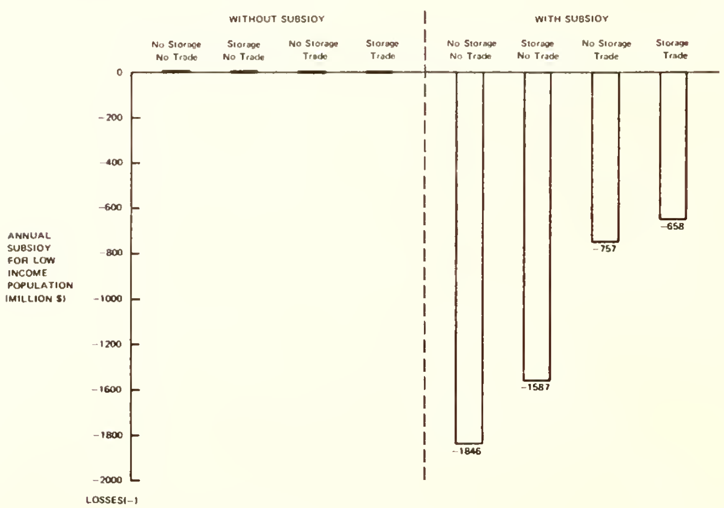
NOTE All storage results with 6 MMT capacity

Figure 15: HOW ALTERNATE POLICIES AFFECT CONSUMER LOSSES



NOTE: All storage results calculated with 6 MMT storage

Figure 16: HOW ALTERNATE POLICIES AFFECT THE LEVEL OF SUBSIDY PAYMENTS TO SUPPORT CONSUMPTION OF POOR



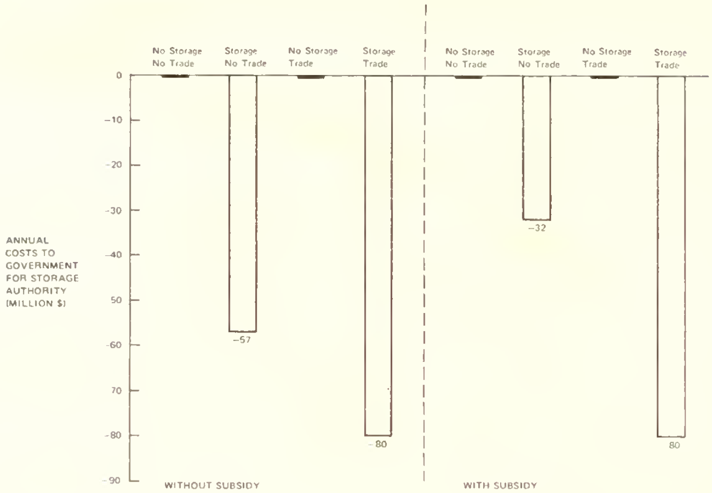
NOTE: All storage results calculated with 6 MMT capacity

Consumers /11/ lose financially from either storage, trade, or subsidies alone (Figure 15). Given the existence of a subsidy program, however, either storage or trade provide a marginal benefit (fewer costs) to consumers. In the absence of a subsidy policy, consumers may favor (in financial terms alone) neither increased foreign trade nor a grain reserve. If a subsidy program exists, they may favor either storage or trade, alone or together. Trade alone provides the largest incremental benefit to consumers given a subsidy program.

For a government with a subsidy program, either storage or trade reduce the financial costs of the subsidy (Figure 18). Trade alone is far better at improving the government's total accounts. A buffer stock, either alone or with trade, works to reduce government losses. The major impact on buffer stocks is to reduce subsidy payment, as shown in Figure 16. The government's storage authority will tend to lose financially from the operation of a reserve - it is not a profitable investment by private accounting standards (Figure 17).

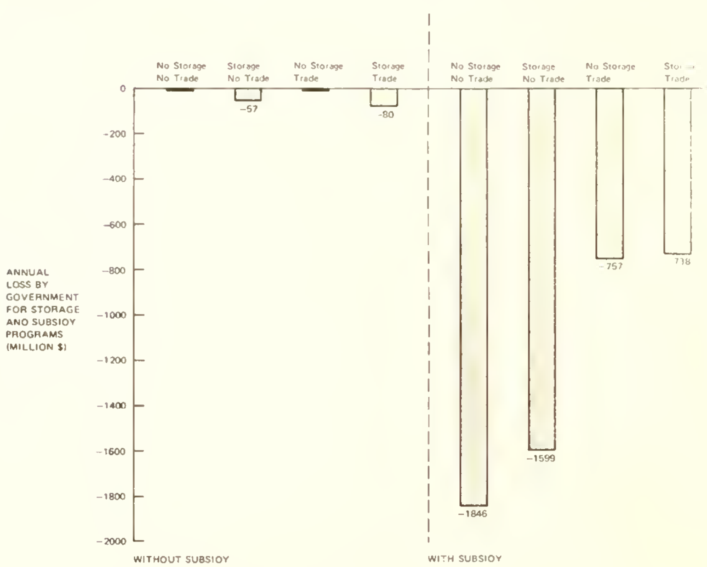
/11/ The subsidy does benefit the poor. However, in the absence of trade any increase in consumption by the poor decreases consumption by other consumers in an equal amount. Since this latter group's demand is more inelastic, there is a net loss in consumer welfare, when distributional benefits are ignored.

Figure 17. HOW ALTERNATE POLICIES AFFECT THE FINANCIAL BALANCE SHEET OF THE STORAGE AUTHORITY



NOTE All storage results calculated with 6 MMT capacity

Figure 18. HOW ALTERNATE POLICIES AFFECT THE LEVEL OF TOTAL GOVERNMENT ACCOUNTS



NOTE All storage results calculated with 6 MMT storage capacity

SUMMARY

A grain reserve reduces fluctuations of grain supplies, market prices, and the balance of foreign trade. Low stock levels provide significant incremental stability, but there are decreasing marginal stabilization returns to increases in stock capacity.

Costs of a reserve usually exceed its benefits. A buffer stock will in most cases be both an unprofitable private investment and an inefficient use of public funds. Economic losses increase with the size of the reserve. The marginal cost per 'unit' of stabilization rises sharply as stock levels are increased.

The income distribution effects of a grain reserve are strongly influenced by the existing trade and/or subsidy policies. The direction of these effects sometimes change with increasing levels of storage activity.

If the country has a consumption maintenance policy for low income consumers, the government realizes substantial savings in the cost of the subsidy program with the establishment of a grain reserve. These savings far exceed the financial loss to the storage authority of operating the reserve at moderate levels of stocks.

Leaving aside the political considerations of choice among the goals of social policy, trade seems to be most effective in meeting many of the objectives. The purposes for establishment of a grain reserve may be better served by first freeing trade. Storage may be viewed as a policy option which can supplement trade. Furthermore, only by freeing trade is it likely to be financially feasible to pursue a food grain consumption maintenance program for people living at the margin of adequate nutrition.

The conclusions discussed herein are limited by our consideration of a particular hypothetical LDC. This nation was a normally self-sufficient country, whose production is non-responsive to price expectations and not correlated with world production or price fluctuations. Work is currently underway to modify the model to accommodate a wider range of more realistic assumptions.

The quantitative results are obviously only illustrative. We believe that the simulation model described in this study can be easily adapted to the evaluation of specific investment decision problems regarding grain reserves in less developed countries.

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A METHOD TO SIZE WORLD GRAIN RESERVES: INITIAL RESULTS

by

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ABSTRACT

The role of a buffer stock is to ameliorate short run problems of variation in food production. Of the many assumptions which could be made concerning human institutions and grain production in the future, we chose a set which permits a determination of a lower bound on global grain reserve size. A multiobjective linear programming method which can determine how much grain is needed for reliable world food security is developed and applied. Complete stabilization of the levels of grain available for use would require at least 172 million metric tons, or fourteen percent of the total 1974 world grain harvests. Without a reserve, in an extreme event of productive shortfall, grain available for use could be five and a half percent below the expected volume of production. There are tradeoffs between food security, reliable performance, and the size of a reserve, in that greater security and reliability can only be gained at the expense of a larger reserve. Additional information that may be of value for buffer stock decisions may be gained through the use of alternate assumptions or criteria to assess a global buffer stock.

INTRODUCTION

The patriarch Joseph rose from slave to be Viceroy of Egypt by developing a grain storage program. Without a computer, he determined how much grain should be saved during the seven fat years to stabilize supplies and thus prevent famine during the subsequent seven lean years. [1], (1)

Agricultural production has become more efficient over the past 3600 years, but the problem of stabilizing grain supplies has again become important. The population explosion and climatic variability confront us with the question of whether food supplies might be insufficient to feed humankind everywhere during one of those lean years, let alone a series of seven in succession. Joseph's problem was not insuring that food supplies will always outrace nutritional needs; such ultimate issues are beyond a mere technician's control. His concern was how much grain it takes to temporize, to alleviate the impacts of an isolated disruption in production, to postpone the paying of a Malthusian piper.

Three technical issues to be resolved are how large should a reserve be; what price or quantity rules should trigger acquisition or release of stocks; and who will gain or lose from a reserve. This presentation will be concerned with only the first issue, determination of reserve size. The other issues are discussed elsewhere.[2]

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[1] Brackets, [], denote footnotes at the bottom of each page. Underscored numbers in parentheses (_) refer to references listed at the end of this paper.

[2] Space does not permit complete citation of all publications on grain reserves. The interested reader should consult (14) for a review of the

A decision to save grain in a time of plenty for use in a period of want may be made for four different purposes. There is a *marketing reserve*, where grain after harvest is stored as a working stock for graduate use over the remainder of the growing cycle. The *buffer reserve* concept involves saving grain in a year of excellent harvests for use in another year plagued by poor production. Grain set aside even during a year of productive shortfall for distribution for domestic or foreign persons defined as 'needy' is a *food aid reserve*. An *emergency food reserve* is a final stock form, for dispatch to a site of natural disaster or civil disorder. These four reserve varieties can be distinguished by the certainty of demand, the rate of stock turnover, and the social function. Table 1 states these differences.

The Joseph Problem involves food security, and thus this presentation will concentrate upon the year-to-year buffer stock.[3] This issue of reserve sizing has both physical and political dimensions.

RESERVE SIZING - PHYSICAL ISSUES

The physical question of a global buffer stock is how large need a reserve be to provide *reliable food security* during the last year of a sequence of lean years. If a reserve can stabilize the quantities of available grain during such an *extreme event* of productive shortfall, it will, by definition, perform as a better buffer during other years.

Reserve size is defined as the smallest maximum storage level needed to meet a given food security goal with a stated reliability. *Reliability* is the probability that a given reserve size will provide *food security* in an *extreme event* of productive shortfall. *Reliability* statements can be made through an application of the theory of order statistics [4], which is explained elsewhere.(3)

The term *extreme event* is a term used throughout this paper. It refers to the year of lowest grain availability due to the most pessimistic series of sequential global crop failures that could occur in the future on the basis of historical fluctuations in world total grain production. The *extreme event* for Joseph was the last of the seven lean years.

Food security is defined in terms of stabilization of the quantity of grain that can be made available for use in the extreme shortfall event. Food security is the fraction of the expected production volume (the expected value of the random variable, production) to be available for consumption in this

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[2] 'classical' literature; the other articles in this volume as examples of current research; and (6) and (10) for policy oriented discussions of world reserves

[3] Analytical methods can be developed to aid decisions regarding the other three reserve varieties.

[4] This is a modification of methods stated in (12).

TABLE 1: FOUR TYPES OF GRAIN RESERVES

RESERVE TYPE	DEMAND CERTAINTY	RATE OF RESERVE TURNOVER	SOCIAL FUNCTION
working stock	relatively certain	disposed of within one year or growing cycle	intra-year stabilization
buffer stock	uncertain	buildup and release rules set time in storage	inter-year stabilization
food aid reserve	relatively certain	determined by 'need' of target group	political leverage of humanitarian use
emergency reserve	uncertain	depends upon what is defined as an emergency	humanitarian use

worst of all possible years. In years where production exceeds the expected volume, grain may be added to the buffer stock and thus use reduced towards the level of expected production. In lean times, grain can be withdrawn, allowing the level of grain available for consumption to rise towards the expected production volume. Perfect food security, in this definition, is achieved when grain use in every year is equal to the expected volume of production. We recognize that other researchers might prefer alternate definitions for food security. Our reasons for using this *food security* definition are presented elsewhere.(3)

The physical existence of a stock is but one necessary condition for assuring that grain will be available to a target population. Other necessary conditions include: (1) that a reserve is not destroyed by fungal or rodent infestation; (2) that the target user groups own, can purchase, barter for, or in some other way gain access to the grain; (3) that a transportation and distribution network exists to move the grain to the users; and (4) that the target group possesses a health status in which they can utilize nutrients from the grain.

RESERVE SIZING - OBJECTIVES

Any decisions regarding the size of global buffer stocks will be made within a context of competing, political interests. We recognize that alternate views exist for assessing the utility of grain stock size. A farmer might wish a reserve to maximize his profits. An economist might insist upon maximizing net economic efficiency benefits. A mother of a starving child might evaluate reserve size by its ability to reliably buffer the quantities of available grain. The government of an importing nation might wish to minimize the price deviations of grain on the world market. While each person has biases about priorities among these and other objectives[5], an independent analyst should not bend to any one objective as a true goal.[6] Analysis

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[5] Some of the alternate objectives for evaluating grain reserve size are: (a) maximization of net economic efficiency benefits (aggregate consumption); (b) maximization of producer profits; (c) maximization of consumer surplus; (d) minimization of costs to the storage authority; (e) minimization of deviation in the market price of grain; (f) minimization of the maximum market price of grain; (g) maximization of the minimum market price of grain; (h) minimization of the size of a grain reserve; (i) maximization of the probability that a reserve will meet a designated food security target; and (j) maximization of food security.

[6] There is a peculiar litany among some economists that the only 'true' social objective is "economic efficiency". However, as Marglin has so aptly stated: "The problem is that the assumptions of most models of welfare economics preclude consideration of dimensions of welfare other than the size and distribution of consumption; moreover, the institutional bars to the attainment of desirable distributions of consumption are ignored... This environment makes the singleminded pursuit of 'efficiency' — in its

should show the full range of physical feasibility and the implications of adopting any particular priority ranking of objectives, not report a single 'optimal' answer. In this paper, as a first research step, a buffer stock is evaluated in the context of three objectives: reserve size, food security and reliability.[7]

RESERVE SIZING - ASSUMPTIONS

In order to determine reserve size, it is necessary to make some assumptions regarding the human institutions through which grain is produced, processed, stored, marketed, transported, distributed, and consumed. In this paper, as a first research step, we have adopted a procedure for making assumptions concerning these human institutions. We select an assumption if it tends to lower the result of this sizing analysis in comparison to what would be derived on the basis of alternate assumptions. Our goal is to find the *lower bound*, the smallest buffer stock size, that could occur under any set of assumptions regarding these systems. We have chosen this lower bound approach rather than select 'realistic' or 'over-design' assumptions because a lower bound is a practical negotiating position. We tolerate, even require bridges which are over-designed by factors of 10 or 100 to hold up a maximum load. In a grain reserve, such a policy of over design could be expensive and politically risky. We would argue that a realistic reserve should be at least as large if not larger than a lower bound, if a food security target is to be met with a designated reliability. This lower bound analysis is a first minimal research step.(3)

Our assumptions concerning trade, transportation and distribution systems, inter-substitution between grains, and the scale of the reserve are presented in Table 2. All these assumptions produce lower estimates of reserve size than alternate, more realistic assumptions. For example, a set of many uncoordinated national reserves, each of which is designed to make its owner 'grain independent' is likely to be larger in aggregate than a single 'free trade' global reserve or reserves operated under international agreements.[8] A set

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[6] particular meaning of the maximization of aggregate consumption — an inadequate surrogate for the maximization of ... [social] welfare."

[7] Space limitations restrict the presentation of many details of the research methodology and results; the implications of adopting alternate objectives or assumptions; and the justification of our approach with respect to other techniques. The interested reader will find many of these details in (3). A copy of (3) will be available upon request to David Eaton, c/o DOGEE, Ames 419, The Johns Hopkins University, Baltimore, Maryland 21218.

[8] In the absence of trade or international coordination, it is not possible for a bumper crop in one country to offset the shortfall in another. A world total shortfall, defined as the net sum of national surpluses and shortfalls, is likely to be less than the aggregate of shortfalls. A similar argument holds for inter-crop substitution, where buffering could occur in terms of inter-country offset or intra-country transfers of one grain for another.

TABLE 2: SCALE, TRADE, DISTRIBUTION AND SUBSTITUTION ASSUMPTIONS

SUBJECT	ASSUMPTION OF THIS STUDY	ALTERNATE ASSUMPTIONS FOR FUTURE RESEARCH
trade barriers	free trade	barriers to trade
substitution of one grain for another	perfect substitution of all grains in reserve	separate reserves for each grain - no substitution
transportation or distribution barriers	no barriers	barriers to transportation or distribution
aggregation of reserve	a global reserve	a system of national reserves to meet national needs
		regional reserve systems

of many grain-specific reserves (e.g., for rice alone) to maintain consumer preferences would lead to a higher total grains reserve than where perfect substitution of one grain for another is possible.[8]

STABILIZATION RESULTS

We shall now present a selection of the results of our research. Those motivated readers interested in the analytical techniques which produced these results are directed to later sections of this paper and elsewhere.(3)

In addition to the previous definitions and assumptions, we have also assumed that the variability of grain production will in the future be constant with what it was during the 1960-1974 period. This presupposition, which is discarded elsewhere(3), also tends to lower the result of this sizing analysis in comparison to what would be calculated on the basis of increasing future variability of production.

Complete stabilization of the level of grain available for use would require a reserve of at least 172 million metric tons. This quantity is 14 percent of total 1974 world grains production[9]. It is also 5.7 times the standard deviation of production levels around trend. If no buffer stock were held, the level of grain available for use could fall 5.5 percent below the expected volume of production.

These results can be put in perspective by comparing them to the buffer stock sizing results of Joseph. Joseph saved 20 percent of the total annual grains production in Egypt in each of seven unusually productive years (e.g., when production was above the expected volume)(1). The total sum was probably far in excess of 140 percent of Egypt's expected annual grain production. Thus, Joseph's reserve was proportionally at least *one order of magnitude* larger than the largest reserve size discussed in this paper.

TRADEOFF CURVES

Far richer information of use for policy analysis can be gained by discussing the tradeoffs between the three objectives: reserve size, food security, and reliability. These tradeoffs are best discussed in terms of the tradeoff, or transformation curve. Such a curve shows the full range of physical feasibility and the implications of adopting any particular priority ranking among objectives.

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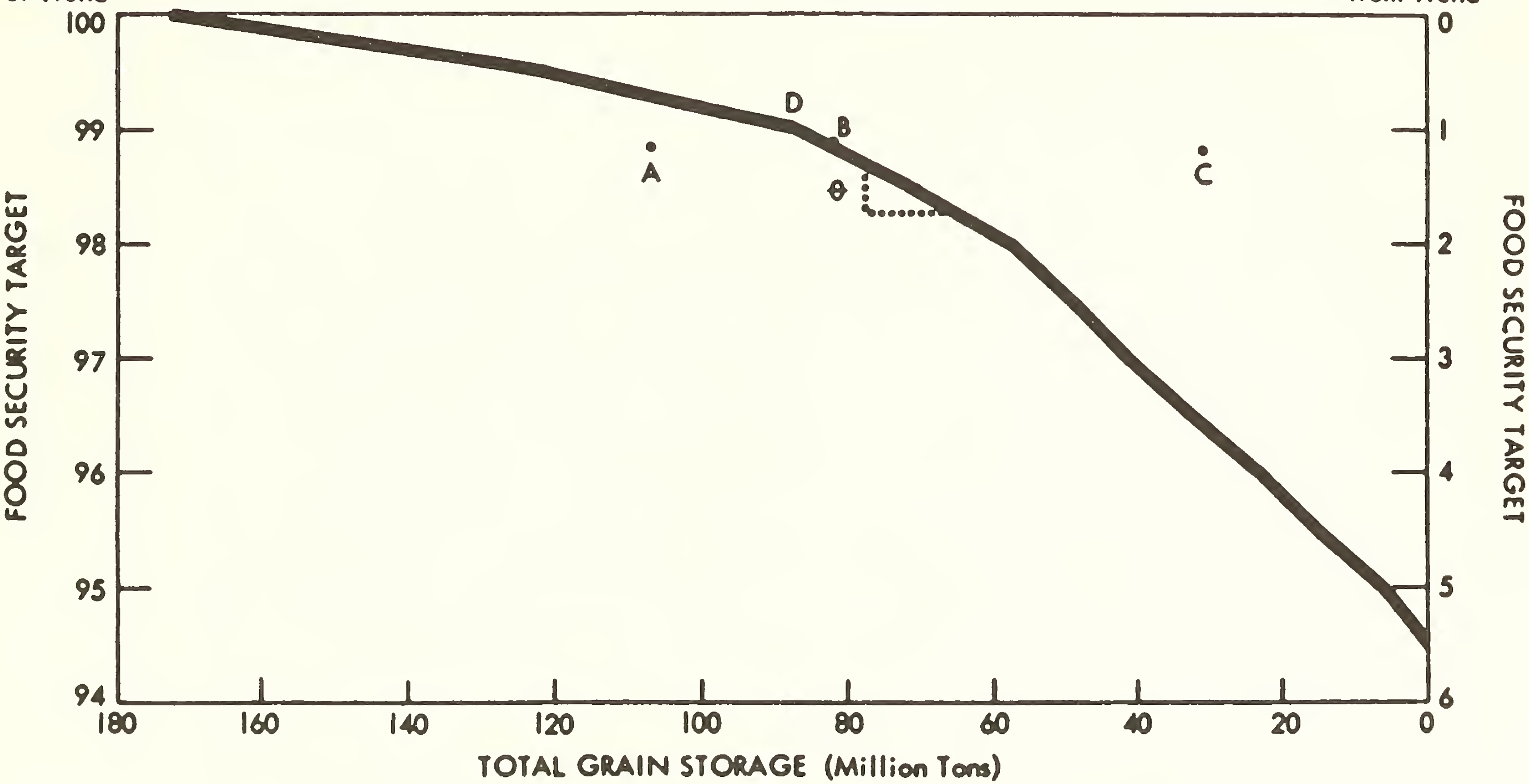
[9] This study used a 1960 to 1974 data series of world total grains production(2). Total grains are defined as the sum of production data for wheat, corn, rice, sorghum, oats, rye, barley, and other food and feed grains. The U. S. Department of Agriculture series was chosen for use, due to its greater accessibility, over a series maintained by the United Nations Food and Agriculture Organization.

FIGURE 1

A HIGHLY RELIABLE* CAPACITY-FOOD SECURITY TRADE OFF CURVE



This curve developed for the period 1975-2000.
*See text for a statement on the degree of reliability.

The curve in Figure 1 shows the tradeoff between food security and the reserve size. A large reserve can provide much security, a small reserve but little. There is a tradeoff between capacity and security in that greater security can be gained only at the expense of a larger reserve.

This transformation curve shows the boundary of the feasible region. All points inside (to the left of) the curve are feasible, but they are dominated by at least one point on the boundary (the curve). All points outside (to the right of) the curve are infeasible. All points on the curve are feasible and cannot be dominated by any other feasible points; it is impossible to unambiguously improve along one objective without a decay in the value of the other. For example, point A is feasible, but it is dominated by point B, since point B achieves an identical level of food security at a lower storage size. Point C would dominate point B, since it achieves an identical level of food security at a lower capacity, but point C is not physically feasible. Points B and D are part of the non-inferior set (the transformation curve); there is an improvement in food security only at a cost of increased reserve size. Thus the points on the transformation curve, and only those points, are of interest as policy alternatives.

The choice of one of the boundary points as an alternative for implementation implies the imposition of a set of preferences for one objective relative to the other. The implicit tradeoff can be made explicit by drawing a tangent line to the curve at the point selected. Such a tangent line has been drawn at point B on Figure 1. In general when the slope of the tangent line to the transformation curve at a point is $-1/\Theta$, the implicit tradeoff between objectives is Θ[10]. In this case, the selection of point B in Figure 1 implies that an incremental one-half percent of food security is worth 15 million metric tons of additional reserve capacity.

RESERVE SIZE VS. FOOD SECURITY

The curve in Figure 1 provides a great deal of information that is of interest for policy. For a designated reliability, it shows how reserve capacity must be increased to gain any desired level of food security. The capacity-security tradeoff varies as one goes along the curve. Thus, moving from 95 percent to 96 percent levels of security requires 17 million metric tons of additional storage. Covering the final incremental percent, from 99 percent to 100 percent, requires 84 million metric tons. As might be expected, the final increments are less cost-effective than the first increments.

Figure 1 is described as a "highly reliable capacity-food security tradeoff curve". What is meant here is that we have used the order-statistics methodology to explicitly bound any estimate of reliability.[11] In particular,

[10] At any corner point, such as point D, there is a right tradeoff and a left tradeoff. No unique tradeoff exists due to the fact that the tangent at D is undefined.
[11] See footnote [7] and (3).

we have selected two such estimates of reliability, 0.90 and 0.95, and can state that any points on the curve in Figure 1 will meet the designated food security targets with the following probabilities:

$$P(\hat{R} \geq .90) = 0.97 \; ; \; P(\hat{R} \geq .95) = 0.83 \qquad (1)$$

where P( ) = Z is a probability statement that the expression in paranthesis is equal to Z, where $0 \leq Z \leq 1$; $\hat{R}$ is the true underlying reliability, or the probability that a given reserve size (or a curve of reserve sizes) will meet a designated food security goal (or set of tradeoff goals); and 0.90 and 0.95 are two estimates of reliability. The reason for such a second order probability statement is that reliability itself is a random variable whose value will change from sample to sample.

BUFFER RESERVE IMPLICATIONS

Granted the assumptions, operational definitions, and methods of this paper, three conclusions follow:

1. The numerical results in Figure 1 represent highly reliable lower limits upon the capacities of a global grain reserve designed to meet the alternate food security targets.

2. Any reserve of a size below these values will not meet the food security targets with such high reliability.

3. It cannot be determined from these data how much larger than the numerical results in Figure 1 a reserve should be to reliably stabilize grain availability.

For example, grant that a public goal be to provide at least 98 percent of trend production to be available for use during all of the next 25 years. In Figure 1, a reserve of 58 million metric tons of grain is the quantity which reliably meets the 98 percent target level. 58 MMT is about five percent less than the 1974 world total grains production(2). If a buffer stock smaller than 58 MMT was decided upon, then expectations for grain availability to be buffered within two percent of expected production volume would not be warranted. While 58 MMT would be enough to meet the 98 percent food security target under the restrictive assumptions of this study, it might in reality be inadequate. The reader will recall that many previously noted assumptions were adopted precisely because they would lower the reserve capacity in comparison to the size that would be calculated under more 'realistic' assumptions. The quantitative implications of relaxing these 'lower bound' assumptions is an important item of future research(3).

Since reliability is also a criterion, the manner in which the capacity-security tradeoff varies at different reliability levels is relevant information. In Figure 2, three curves are drawn to show the capacity-reliability tradeoff at fixed security level.[12] These alternate security levels are 98, 99, and 100 percent of trend production made available for use during the worst of all possible years during 1975-2000. As the target of food security increases, the curve shifts to the right; meeting a higher target of food security at a constant reliability requires a larger grain reserve. For example, a reserve of 50 MMT is sufficient to meet the 98 percent target with an estimated reliability greater than 0.9 (Point H). The same reserve size has no chance of meeting a 100 percent food security target. A gap of about 15-20 MMT separates equally reliable performances for the 98 percent and 99 percent targets. Moving the final incremental percent is relatively more costly, requiring 45-60 MMT.

There are also tradeoffs between reserve size and the estimated reliability. By increasing reserve size from 40 to 60 MMT, in terms of the 99 percent security target, the reliability of performance jumps from 0.35 to 0.87. However, the final increments of reliability are relatively more costly than the initial increments in terms of increased reserve size. To move from 0.86 to 0.97 estimated reliability on the 99 percent target curve requires a reserve increase of 29 MMT.

ANALYTICAL METHODS

In order to produce these results, it was necessary to develop analytical methods to characterize the history of grain production; simulate future grain production; and size a reserve with respect to the multiple objectives. Space limitations preclude a complete development of the methodological approaches here; they are presented elsewhere(3).

Historical Production

We used curve fitting and statistical analysis to characterize three aspects of past production data: (i) how the expected volume of production has changed over time; (ii) the variability of production around the expected volume; and (iii) any effect of surplus or shortage in one year upon production in another year. This method assumes that there exists a pattern in an historical grain production series. It further presupposes that physical (climate, land

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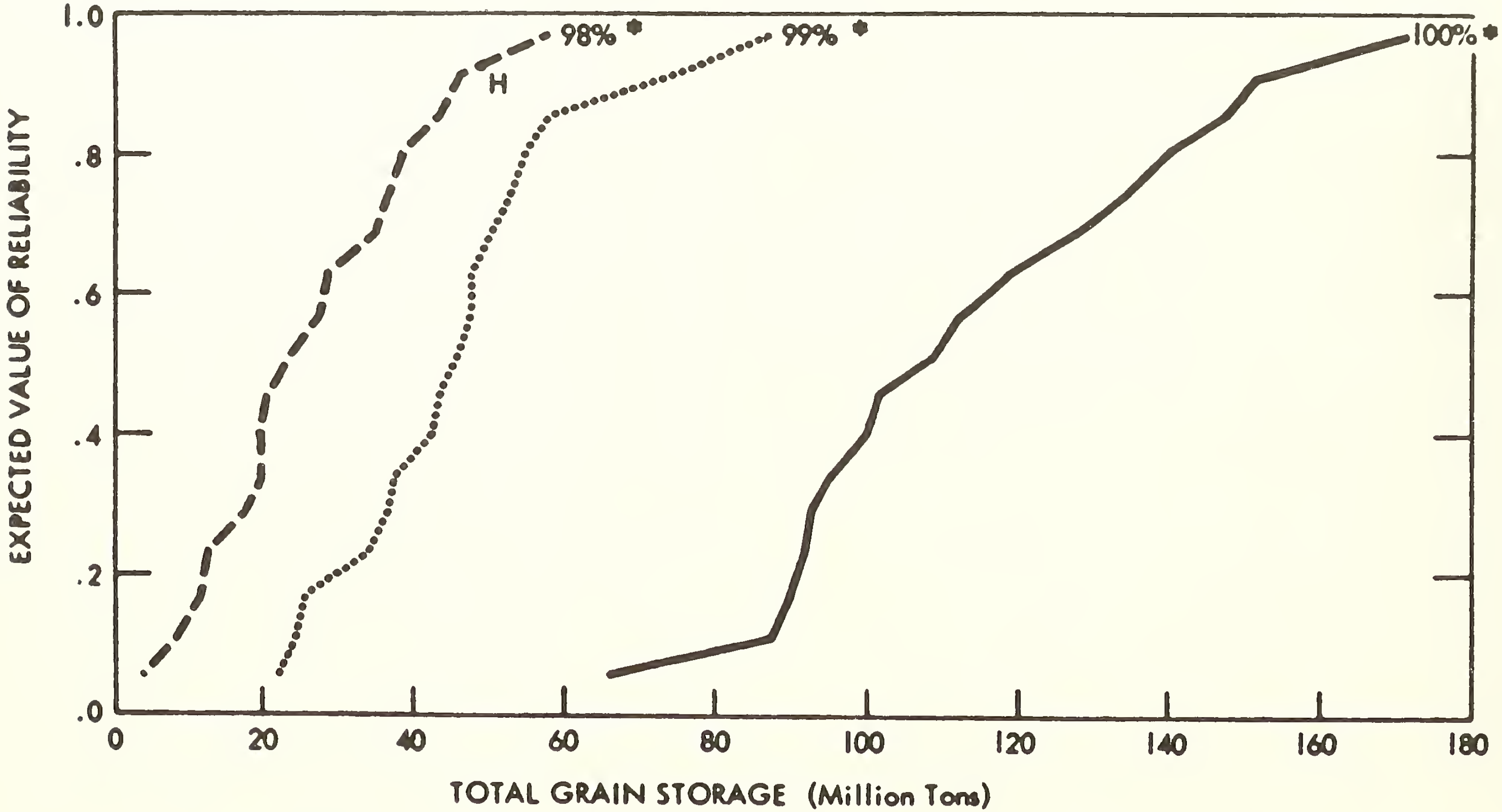
[12] The selection of any point on one of the curves in Figures 2 or 3 as an alternative for implementation implies the imposition of a set of preferences for reserve size relative to reliability of performance. The implicit tradeoff can be made explicit by drawing a tangent line to the curve at the point selected (see note 10). The tradeoff is the value of the slope of the tangent line at the point.

FIGURE 2

RELIABILITY VERSUS STORAGE "COST EFFECTIVENESS" CURVES



* Each value of percent refers to a level of food security coverage (expressed in terms of trend production), during 1975-2000.

fertility, water, fertilizer, etc.) and institutional (prices, government policies, technology, etc.) factors which may determine the production volumes are implicit in the historical data series. We recognize that this procedure is simplistic and that other analysts might prefer the use of scenarios, time series analysis, or physical process simulation to characterize the grain production process (4,5,7,8). The reasons for the use of our techniques are discussed elsewhere(3).

Simulation of Future Production

By assuming that patterns exist in historical data, it was possible to characterize a time series with trend, variability, and lagged co-variance statistics. We then assumed that these patterns can be extended into the future and that storage levels will not affect production behavior. We then derived a generating function which could produce synthetic traces of future world total grains production. Each such scenario is different, but has an identical expected variance and lagged covariance structure as the historical time series. This method (3) is an application of techniques developed for synthetic hydrology(13).

Sizing a Grain Reserve

Given the previous assumptions and analysis, we constructed a multi-objective linear program to optimally size the grain reserve. This method, which is developed in detail elsewhere (3), made it possible to generate the tradeoff curves between food security and reserve size. This reserve sizing method was used to assess grain reserve tradeoffs for the period 1975-2000. The MPSX linear programming algorithm of I.B.M. was used; the average cost per linear programming solution was 0.17 seconds or 21.6 cents.

Reliability Analysis

We used methods based upon the theory of order statistics (12) to evaluate the reliability of reserve sizes and to select the number of synthetic futures for sizing analysis. Expressions for both the expected reliability of a reserve and the probability that the underlying reserve reliability exceeds any given estimate of reliability were derived and applied to the sizing analysis results (3).

DISCUSSION

Only three alternate objectives were employed in this paper to evaluate reserve options: food security, capacity, and reliability. Other important objectives relating to economic efficiency, income distribution, and price fluctuations need to be considered as a basis for assessing the performance of a global grain reserve(3).

Required size or capacity is but one necessary piece of information for the optimal design of a buffer stock. It is still necessary to develop reasonable operating rules based on either prices or production signals, that tell

an operator when to add grain or to release from the reserve. Rarely need a reserve be kept at its maximum level in order to meet its designated food security target with reliability. Alternate price and quantity rules are also to be analyzed in future research(3).

We deliberately avoid recommending one 'optimal size' for a grain reserve. Our purpose is to describe for policy makers the full range of possible technical alternatives and to quantify the implications of adopting one or another bias or assumption.

SUMMARY

The role of a buffer stock is to ameliorate short run problems of variation in food production. Of the many assumptions which could be made concerning human institutions and grain production in the future, we chose a set which permits a determination of a lower bound on global grain reserve size. A multiobjective linear programming method which can determine how much grain is needed for reliable world food security is developed and applied. There are tradeoffs between food security, reliable performance, and the size of a reserve, in that greater security and reliability can only be gained at the expense of a larger reserve. Additional information that may be of value for buffer stock decisions may be gained through the use of alternate assumptions or criteria to assess a global buffer stock.

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AN OPTIMIZATION APPROACH TO GRAIN RESERVES FOR DEVELOPING COUNTRIES

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ABSTRACT

A procedure for calculating optimal grain reserves is developed and applied to developing countries and regions. The calculations assume known demand functions and storage costs and random grain production. Between regions net international trade cannot be adjusted to offset year to year fluctuations in yields and the quantitative effects of trade barriers and regionalization on optimal reserves are indicated. An international insurance program for grains is described and its effects upon optimal reserves are calculated and discussed. Some results for developed regions are also presented.

The increased interest in grain reserves, in the last few years on the part of decision-makers and scholars, has been met by a growing body of research designed to consider various aspects of food carryovers. This paper represents an attempt to specify quantitatively optimal grain carryovers for various countries and regions of the world. We use the concept of optimality in a precisely defined sense and make other particular assumptions which allow the application of a calculation methodology which is developed below to recent data. We deal with those year to year carryovers which might be held against the uncertainties of price caused by variable supplies (or potentially demands). We do not consider the problem of working-stocks nor of holdings over a yearly cycle. Our problem is the costs and gains of quantity arbitrage over time horizons of greater than a single year.

The basic unit of analysis is a single country or region (which may be as large as the whole world) which is then treated as a separate market area. Each region has a stochastic process which represents grain production at each point over the relevant time horizon. This gives information concerning expected supplies for each year and the potential variability of these supplies. The demand facing a region's supply is assumed to follow a deterministic path over time with international trade built into the relevant demand concept to keep this demand equal to long run trend supply at the base price. Thus the long run path of the relative price of grain is deterministic and constant. The price elasticity of demand is an important parameter in the calculation of optimal carryover because it determines the marginal value of moving supplies (over time) from high supply situations to periods of low supply. Storage costs and discounting by the real rate of interest convert the gross positive returns from storage into a net welfare calculation.

Our calculation method, which is developed below, is based directly on the seminal work of Robert L. Gustafson.[1] After setting up the formal procedure to be applied, we discuss the empirical specification of the problem and of each parameter. We have aggregated all cereal crops together using FAO production data. Further we have used the FAO regionalizations because of data convenience and because the empirical results of this paper are meant as representative and not as specific policy proposals. Discussion of the demand and cost specifications of the model is followed by an explanation of the use of time series on grain production to derive forecasted probability distributions for future grain supplies which enter the carryover determination. Our results from applying the model as specified are summarized in Tables 1 to 5 below. A potential international approach to stabilization based on an insurance concept is discussed quantitatively and its impacts on carryovers of countries and regions are presented.

It should be noted explicitly that this analysis does not imply any particular governmental role in the holding of grain carryovers. Our procedures yield an optimal quantity which is equal to that which would be held in a free market situation by private firms under the conditions specified and given

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[1] The intellectual lineage of this dynamic programming approach to grain carryovers goes back through Gustafson [2], to the inventory models of the early 1950's.

that other barriers to such stocks did not exist. The issue of location of stocks within a country or region is also not considered in this paper and would involve spatial optimization based on transport costs, etc. Further we do not discuss specific operations of grain reserves either publicly or privately held.

While our analysis might be used in developing policy proposals both nationally or in an international situation, our purposes here are only to demonstrate the determination of carryover levels under specified conditions.

BASIC MODEL AND EMPIRICAL SPECIFICATION

Formal Model

The next few pages outline the basic formal model and calculation method which was applied to various countries and regions. Begin by specifying a finite end point T periods (years) in the future, where T is large enough so that effects of this finiteness are negligible. Cereal production in year t, denoted X_t is a random variable with probability density $f_t(X_t)$. Supply for year t is

$$S_t = X_t + C_{t-1}$$

the sum of current production and carryover from the previous year denoted C_{t-1}. Consumption in year t is

$$Y_t = S_t - C_t$$

and the relevant welfare measure in period t is a function solely of consumption in that year;

$$W_t = W_t(Y_t).$$

Storage costs of holding supply from t to the next period are

$$G_t = G_t(C_t)$$

and the discount factor for intertemporal exchange is denoted by δ_t.

The problem in a given year is to maximize the expected value of the discounted sum of welfare over the horizon. That is in period ℓ select C_ℓ, $0 \leq C_\ell \leq S$ to maximize:

$$E = \int_{-\infty}^{\infty} \int \dots \int_{-\infty}^{\infty} \sum_{t=\ell}^{T} \left(\delta_t(W_t - G_t) f(X_\ell, X_{\ell+1}, \dots, X_T)\right) dX_\ell \dots dX_T .$$

We employ the assumption of independence of the production distributions across years, so that

$$f(X_\ell, \dots, X_T) = f_\ell(X_\ell) \cdot f_{\ell+1}(X_{\ell+1}) \cdot, \dots, \cdot f_T(X_T).$$

This simplification imposes potentially important restrictions, is empirically testable on past history and will be discussed below with the presentation of our empirical implementation.

For solution, the idea is to work back from the "final" period to the present using knowledge of the realized values of the stochastic supply function to solve the maximization problem. In the "final" period no "future" production is relevant. For the year T, with S_T given, we want to maximize the net welfare,

$$W_T(S_T - C_T) - G_T(C_T).$$

But from the point of view of year T-1, S_T is a random variable because X_T is not yet realized. Letting V_T be the solution to the period T maximization problem for a given supply, we may write the expected value of V_T as

$$EV_T = \int_{-\infty}^{\infty} V_T(X_T + C_{T-1}) f_T(X_T) dX_T.$$

After integration over X_T this is a function of the carryover from the previous period C_{T-1}. So in year T-1 optimal carryover is found as, that C_{T-1} which maximizes

$$W_{T-1}(X_{T-1} + C_{T-2} - C_{T-1}) - G_{T-1}(C_{T-1}) + \delta_T(EV_T(C_{T-1})).$$

This simply says that current loss in welfare in T-1 arising from positive carryover plus the storage costs are balanced against the expected gain from additional supply in year T. The solution values of this problem and the optimal carryover may be written as functions of T-1 supply; $V_{T-1}(S_{T-1})$ and $C_{T-1}(S_{T-1})$ respectively. In T-2, X_{T-1} is still unrealized so S_{T-1} is a random variable. The expectation of the solution value of the problem for T-1 may be written as a function of C_{T-2},

$$EV_{T-1}(C_{T-2}) = \int_{-\infty}^{\infty} V_{T-1}(X_{T-1} + C_{T-2})f_{T-1}(X_{T-1})dX_{T-1}.$$

Generally, then, for period T-k, the problem is to find $0 \leq C_{T-k} \leq S_{T-k}$ to maximize,

$$W_{T-k}(S_{T-k} - C_{T-k}) - G(C_{T-k}) + \;_{T-k}(EV_{T-k+1}(C_{T-k})).$$

The final term subsumes the value of the carryover to the next period given the probability distributions of production for all relevant future periods. (The number of relevant periods obviously depends on the discount factor δ.) So selecting an optimal C_{T-k} requires that S_{T-k} be given or alternatively any potential S_{T-k} may have an optimal C_{T-k} associated with it. Our results reported below are a consequence of this methodology being carried out empirically.

Empirical Specificiation

The solution method calls for a finite horizon after which the value of storage is zero. We set T = 1990 which is 15 years after the year of any of the results we report and is far enough in the future that no finite end point affects are felt on the optimal carryover results. With the horizon set each of the other components of the model may be specified. A constant elasticity demand function with a constant exponential rate of growth over time was the basis of the consumption side of the model. This is represented by:

$$Y_t = \exp(\gamma t) \cdot Ap_t^{\eta},$$

where Y_t is the relevant grain demand in a region and P_t is the price of grain in year t. The parameters are: the growth rate γ, the constant term α, and the price elasticity η.[1] This demand function yields our welfare measure which is simply an index of the area under the demand curve:

$$W_t(Y_t) = \int_{\epsilon}^{Y_t} (A\exp(\gamma t))^{-\eta} \, Y_t^{1/\eta} \, dY_t$$

where ϵ is a small positive number entered for computational convenience. Carrying out the integration:

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[1]This assumption of constant elasticity form of demand might plausibly be altered to test the effect of more complicated demand functions. For example, one might argue for functions in which the price elasticity for grain was very small (in absolute value) for low consumption levels, reflecting the approach to widespread hunger in poor countries, but which had larger elasticity at higher consumption.

$$W_t(Y_t) = \left(A\exp(\gamma t)\right)^{-1/\eta} \cdot \frac{1}{1+1/\eta}\left(Y_t^{(1+1/\eta)} - \varepsilon^{(1+1/\eta)}\right)$$

The model has been applied to various individual countries and regional aggregates which, within the context of the model, are then held, in a specific sense, separate from the international market in cereals. Given a particular country or region we allowed for free market movement of grain within the unit but assumed that trade with the outside world was not available to offset year to year variation in own supply. In each year the "normal" levels of imports or exports of grain are committed so that the "relevant" demand for a region's carryover calculation is that demand (including net "normal" international trade) that may be expected to be met by domestic supply. It is assumed that long range adjustments in domestic demand and supply in trade will be made to keep this equilibrium in the "normal" levels. Thus, the function of regional carryovers is only to meet the short term fluctuations. If the world as a whole were the only relevant market unit for grain only the relative fluctuation in aggregate world supply would be relevant for carryover calculation. However, given policy restrictions and other barriers, it may be appropriate to estimate optimal carryovers for smaller market aggregates.[3]

To operationalize these ideas we calculated A from

$$A = Y_m P_m^{-\eta}$$

where $t = m$ was taken as a convenient base year. P_m is an approximation of grain price for the region[4] and Y_m is set equal to the trend level of regional grain production in year m. Thus Y_m includes what would have been "normal" exports or imports in that year added to or subtracted from domestic demand. In order to keep this condition throughout the horizon γ was set equal to the

[3]The recent famines in Africa suggest that in some cases transportation costs of moving grain within a country or region at short notice might dictate very small geographical units for carryover analysis or alternatively may suggest a particular locational distribution of storage throughout a region. Further, by adjusting the extent and composition of regions one may approximate the effects of wider scope of free trade on the analysis. Our units of aggregation range from individual small countries to the entire world. However, with the numerous governmental interferences in trade in grains the full problem of adequately incorporating international trade is extremely complex and has not yet been solved.

[4]These prices were based roughly on FAO Trade Year Book data, and were in the range of \$100 per metric ton for most regions. Region differences are mainly a reflection of different compositions of the all-cereal aggregate of wheat, rice and coarse grains. Since price enters only to set levels, the carryovers were relatively insensitive to variations in price in the range of \$20 or \$30.

growth rate in production which was estimated for the supply side of the model from past grain production data as described below.

Our measures of η, the price elasticity of demand, were approximated after considering regional estimates made by Rojko et al. [3] of the USDA. After calculating the appropriate weighted aggregates of these individual own and cross elasticities for wheat, rice and coarse grains, we arrived at an estimate of own price elasticity of all grains.[5] These elasticities ranged between -0.10 and -0.30 but since it may be true that demand becomes more inelastic at higher prices we chose to use the lower absolute value elasticity in most of our work. Optimal carryovers were quite sensitive to changes of η over this range as was to be expected. A 5% drop in supply implies a 50% rise in price at $\eta = -0.1$ and only a 15% rise in price at $\eta = -0.3$. The carryovers reported below based on $\eta = 0.1$ may then be overestimates of the optimal carryover if demand were truly more elastic.

A simple cost of storage function of the form,

$$G_t = MC_t$$

was applied, where M is the average and marginal yearly cost per ton of storing grain including in and out charges and physical loss. For simplicity we used M = $7.50 for all regions and this was held constant over time. Long range real rate of interest was held constant for all regions at 5% leading to the discontent factor, $\delta_t = (\frac{1}{1.05})^t$.

The assumption that the demand function relevant to carryover calculations follows a deterministic trend equal to that predicted for production implies that the probability distribution of domestic prices over the whole horizon will be generated only by the probability distribution of production. World trade price or long run resource costs of grain are thus held to be deterministic and constant. Further, because the adjustments are made sequentially to keep expected excess demand equal to zero at base price, no long term variance of the prediction of production is relevant for carryover decisions. That is, the potential variability in production that is appropriately used to specify the $f_t(X_t)$ over the horizon includes only variance in

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[5]The own price elasticity for all grain G with respect to its relative price Pg was computed as:

$$\eta_{g,Pg} = \frac{W}{G}(\eta_{W,\ Pw} + \eta_{W,\ Pr} + \eta_{W,\ Pc}) + \frac{R}{G}(\eta_{R,\ Pw} + \eta_{R,\ Pr} +$$

$$\eta_{Rm\ Pc}) + \frac{C}{G}(\eta_{C,\ Pw} + \eta_{C,\ Pr} + \eta_{C,\ Pc})$$

when W, R and C refer to wheat, rice and corn, and Pw, Pr and Pc are their respective prices. Each $\eta_{i,\ j}$ is the elasticity of cereal type i with respect to the price of j.

the production distribution itself, not the variance embodied in the estimates of parameters used to forecast production. Insofar as those estimates deviate from true parameters the long term adjustments on the demand side correct for the error.

Time series of grain production from the FAO were used to develop the forecasts of the probability distributions $f_t(X_t)$ for each year t of the carryover horizon. In order to convert information about grain production in the past into useful information about the future a simple log linear trend was estimated. For each country or region

$$\ln X_i = \alpha + \beta i + U_i, \; i = i_1, \; . \; . \; . \; , \; i_n$$

was fit by OLS, where X_i is production in each year i for which the FAO data was available (in most cases i runs from 1948 to 1973). The estimates of α, β $(\hat{\alpha}, \hat{\beta})$ and $\hat{U}_i = \ln X_i - (\hat{\alpha} + \hat{\beta} i)$ were used to generate a probability distribution for each of the years $t = m, \; . \; . \; . \; , T$ of the carryover horizon. For each year, each production quantity

$$\hat{X}_{ti} = \exp\,(\hat{\alpha} + \hat{\beta} t + \hat{U}_i) \quad i = i_1, \; . \; . \; . \; , \; i_n$$

was assigned equal probability. For example with n = 26 and t = 1975, $f_{75}(X_{75})$ is a multinominal distribution with each point assigned a probability of approximately 0.0385.[6] So that while the theory above was framed with continuous distributions our computation used discrete probability distributions.

Because of the log linear specification of production trends with an additive disturbance term, the variability in production is assumed to be a constant proportion of trend production. That is, homoskedasticity of the disturbance over the fitted period extended to the carryover horizon implies that the variability from trend production enters multiplicatively. Thus as expected production grows at rate $\hat{\beta}$ over the time the absolute variation also grows at that rate. For example the probability of a 5% shortfall below trend production will be equal in each year while the probability of, say, a 5 ton shortfall will increase over time as expected production rises. This specification of production variability is very important to the implied optimal carryover results. Assuming constant proportional variability implies that, given constant elasticity demand, the incentive to storage will remain constant

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[6]An alternative specification would have been to use a regression estimate of the variance of production together with an assumption of the form of the probability distribution of production to generate distributions with this estimated variance over the carryover horizon. For example, if U_i were assumed normally distributed this would imply log normal production and the estimated variance on the U_i would yield a particular predicted dispersion of the X_t at any year in the horizon.

over time. Since equal proportional deviations from trend supply generate equal price changes a falling proportional variability, as mean production grew over time, would imply falling carryover amounts. In fitting the model to available data we found no evidence to suggest a rejection of the assumption of homoskedasticity in the U_i. Obviously it is an empirical issue and the predicted trend in variability of production depends on what factors are behind the expected growth in mean production levels. Increases in yield per acre due to new varieties and additional fertilizer may have different implications for production variability from increases in the area planted to cereal crops.

Both our computational procedure and our estimation of the production time series have imposed independence of production probability distributions over time. In the regression the classical assumption of zero covariances between any U_iU_j, $i \neq j$ was made. When applied to the carryover horizon this assumption implies that the probability of, say, a 5 percent shortfall in year t is unaffected by the realized production in year t-1. Alternatively positive autocorrelation would mean that above trend production in t-1 would make above trend production more likely in t and likewise shortfalls would tend to follow one another.[7] Obviously a storage policy should take such information into account. A further implication of non-independence of the probability distributions over time would be that the best forecasted production in year t would depend on the realization of the production level in the previous period or periods. In this case the forecasted trend production would not follow any smooth path but would include "predicted" fluctuations.

Fluctuation in the forecasted production may result from either a simple trend model with non-independence or from a more complicated forecasting model which includes other "explanatory" variables. Given this fluctuation its implication for domestic price response must be consdiered. If the base price demand remained on a simple exponential trend determined by long run factors then the "expected" deviations from trend production would produce price movements and hence would affect optimal storage. Alternatively if international trade were responsive to predicted production fluctuations then the relevant demand, inclusive of trade, might follow the path of predicted supply and thus meet the expected variations to hold domestic base price constant. In such a model only unexpected supply variability would generate a carryover response with international trade adjusting to expected fluctuation. Choosing between these potential specifications is again an empirical issue and in fact turns on geography, institution and policy. In applying forecasting models to the carryover decision the assumption of the time lag for trade adjustments is vital. For example in some situations international trade agreements may offset yearly changes in acres planted so that only yield variability would enter

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[7]Some analysis of the independence of the production time series over the data period was conducted using runs tests and Box-Jenkins [1] time series techniques. So called ARIMA models were fit to the available data and it was found that for most countries and regions the independence assumption roughly held. Further investigation of both the appropriate auto-covariance structure of grain production time series and of implication of nonindependence on optimal storage is certainly in order.

the probability distributions used in the storage model. As is discussed above our applications are implicitly based on a year long lag in trade adjustments to supply and our predicted production follows a smooth trend so full variability in production (but not prediction error) enters into the dispersion $f_t(X_t)$.

RESULTS

Results of applying the method and empirical specifications described in the first section to selected countries and regions of the world are presented and discussed in this section. The model was applied under alternative assumptions to illustrate various aspects of the optimal carryover analysis. Our focus is on developing countries and regions though some results for developed regions may be of interest and are included below. This section is in two parts. The first deals with direct applications of the optimal carryover model, while the second presents and discusses a proposal for an international insurance program for cereals and analyzes its impact on optimal carryovers. We conclude with a brief summary of the method and results of this paper and suggestions for continuing the research.

Optimal Carryovers under Specified Conditions

The model generates an optimal carryover amount for each year of the horizon given a supply level for that year. Supply in a year t is the carryover from the previous year plus current year's production and hence is stochastic prior to year t. At any time prior to a given year t a probability distribution on optimal carryovers for that year may be computed based on the probability distributions of production in the years leading up to year t and some given beginning year supply level. We have computed such a probability distribution of optimal carryovers for 1975 based on the specification described in the first section and conditioned on a given supply equal to trend production for the year 1970. Thus given this 1970 supply as a starting point the probability distributions in each ensuing years determined the distributions of supplies for the next year up to 1975. For 1975 we then have the combination of the probability distributions of 1974 carryover and 1975 production which in turn determine a probability distribution of optimal carryovers for 1975. The results of such an experiment for various countries and regions are summarized in Table 1. It should be stressed that the input into these calculations is such that it applies to calculating the likelihood of levels of carryovers in future years and is not based on the best information which would actually be available for carryover decision in that year. We would have just as easily chosen 1980 as our example year for the results reported in Table 1. Below in Table 2 we illustrate in alternative experiment which uses more directly the information for years just prior to the decision year.

Table 1 shows three points on the cumulative probability distribution of 1975 optimal carryovers for some selected countries and regions based on the experiment described in the previous paragraph. The quantities which would

TABLE 1

OPTIMAL CARRYOVERS FOR SELECTED COUNTRIES AND REGIONS, 1975

(million tons)

Country or Region	1975 Trend Production	Cumulative Probability Levels		
		0.50	0.75	0.95
	A. Demand elasticity η = -.10			
Burma	6	0.3	0.7	1.2
India	100	6.5	9.5	13.5
Indonesia	16	1.6	2.9	4.4
Pakistan-Bangladesh	23	1.4	2.4	4.2
Philippines	6	0.1	0.2	0.3
Thailand	13	3.5	4.7	6.2
Other Far East	19	1.4	2.1	3.1
Africa	46	1.5	3.0	5.0
Far East	184	3.0	7.5	12.5
Latin America	78	2.5	5.0	8.5
Near East	48	2.5	4.5	8.5
All Developing Regions	353	2.5	7.5	15.0
Europe	231	1.3	5.5	9.5
North America	270	10.0	18.0	33.0
Oceania	18	8.0	10.5	15.4
USSR	199	28.0	41.0	49.0
World	1,304	0.0	2.0	18.0
	B. Demand elasticity η = -.20			
India		2.0	4.0	7.5
Africa		0.0	0.5	2.5
Far East		0.0	1.0	7.0
Developing Regions		0.0	1.0	7.0
North America		1.5	8.5	22.0
USSR		13.0	24.0	37.0
World		0.0	0.0	7.0

cover the lower 0.50, 0.75 and 0.95 portion of the cumulative probability distributions are displayed in the respective columns.[8] Thus for India optimal

[8]The data for the estimation of the probability distributions of production come from FAO Production Yearbooks [4]. Our definitions of countries and regions are thus based on these FAO breakdowns. Each of the developing regions

carryover would have been 6.5 million tons or less with 0.50 probability; 9.5 million tons or less with 0.75 probability and the probability is 0.95 that carryover would have been 13.5 million tons or less. For purposes of comparison 1975 trend production levels for each entry are also listed.

Several points should be discussed concerning the results of Table 1. First, note that there are considerable differences across countries and regions in their optimal carryovers relative to their trend production levels. These differences are mainly due to differences in the variability of production. For example, at the 0.75 probability level Africa has a carryover of less than 4 percent of trend production while the Near East the indicated carryover is 9.5 percent of trend production. From the time series analysis of production trends Africa had a variance of residuals of 0.23×10^{-2} while that of the Near East was $.68 \times 10^{-2}$. The extremes are even greater for the individual countries of the Far East region. The effect of the variability of production over time is related to the implications of aggregation on optimal carryovers. The larger the aggregate the more scope for inter-spatial vs. intertemporal arbitrage to offset production variability.

In our model, within each unit of analysis a single market prevails so that only supply variability of the whole region causes price fluctuation. When the covariance of production across regions is not perfect the fluctuations in production will be offsetting and hence lead to less optimal carryover. The results of such offsetting variations may be noted from Table 1. In the top portion of that table the Far East region has been broken down into five individual countries plus Bangladesh--Pakistan, and all other countries. Note that with this disaggregation India alone has as large an optimal carryover as the whole Far East region when treated as a single unit. The impact of aggregation may also be seen by noting the rows for All Developing Regions and the Whole World. Because covariance between optimal carryovers is not unity, the probability distribution of the sum of carryovers in each region is not simply the sum of the carryovers under each probability level. However we can easily compare the expected values of optimal carryovers under disaggregation compared to aggregation. The expected value of the sum of the optimal carryovers of the 7 countries and groups which make up the Far East is the sum of the expected values of the carryovers for these countries, which is 16.7 million tons. The expected value of carryover for the Far East is 4.5 million tons. For the four developing regions the expected value of the sum of the carryovers is 13.7 million tons compared to 5.0 million tons for the Developing Regions. This impact of regionalization on the probabilities of optimal carryovers demonstrates the value of reducing international barriers to quick and

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refers to non-centrally planned developing countries in a given area. For details see any FAO Yearbook or other publication. With respect to the developed regions we broke with the FAO regionalization to use the FAO defined continental Europe rather than just the developed market region. Our all grain aggregate follows the FAO data except that we have converted rice paddy to the usable grain by a 0.65 conversion factor. Further information on our time series analysis on grain production and the specification of other inputs into our calculations can be made available on request.

free movement of cereals in a world market. Some impediments to short term trade are geographical and technical but others are institutional and a function of policy. These regionalization examples also show the importance of very careful attention to the appropriate specification of region trade considerations when actual applications for policy are made using this framework.

Also included in Table 1 are results of applying the model to some of the FAO defined developed regions. These results are informative and show that especially for the USSR and Oceania carryovers become quite sizable relative to trend production. In both of these regions grain production is much more variable than in any other major producing areas. The application to the developed regions and to the world as a whole is more preliminary than the analysis of the developing regions because some of our maintained assumptions may be more at variance with reality for these regions. Specifically, the assumptions of: (1) non-stochastic demand, (2) no variability offsetting trade, and (3) deterministic and stable long run world market grain prices, cause more problems for these regions that include major exporters. Regions like North America and Oceania which export a significant part of their grain production face a world market for grain which may violate more drastically than for importers our assumption of non-stochastic demand. To some degree the demands they face depend on stochastic elements in production in other countries. Further exporters may have lower costs of short run changes in their trade arrangement, thus a large crop might be sold in part to new buyers and would drive down the price less than is indicated by our model. Finally for these regions and especially for the world as a whole, the long run world market price cannot be considered deterministic. The price on traded grain is stochastic and must be estimated. Thus the choice between carryovers or the use of future production should include the fact that even at mean production the future base price cannot be known with certainty. For the world as a whole especially there is no possibility in adjusting trends in production and demand by imports or exports as some stable world market price. This means that estimation error in determination of production trends is a relevant component of the variability of future production which generates an incentive to carryovers. Fortunately our regression for world grain production trends fit very well and such variance from prediction error is not large.

For comparison with the results of Table 1 the calculations reported there were repeated for some of the countries and regions using a price elasticity of demand of $\eta = -.2$. Table 1.B summarizes the significant effects of the greater elasticity in reducing the optimal carryover quantities. Since our knowledge of the appropriate price elasticities is weak we can only suggest that these results are illustrative. The USDA estimates of Royko et al. lend credence to the belief that assumptions in the range of -0.1 or -0.2 are not far off for most countries and regions.

In Table 2 we report on a somewhat different application of the model. The optimal carryover quantities for each of the years 1968 through 1974 were calculated based on actual production in those years. In order to more closely approximate actual conditions the estimates of the potential variability of production were based on residuals prior to each decision year. Thus for 1968 on the values of $\hat{U}_i$ from 1948 through 1967 were used. Results are presented for India and Africa. For India it was assumed that no carryovers were held in

1967. Both 1965 and 1966 were very bad years in India and 1967 had below trend grain output. For Africa 1967 carryovers were assumed to be one million tons which is also reasonable since 1967 was just above trend production and followed a bad crop in 1966.

TABLE 2

EFFECTS OF CARRYOVER PROGRAM ON AVAILABLE SUPPLY BASED ON ACTUAL PRODUCTION, INDIA AND AFRICA, 1968-1975

(million tons)

Year	Actual Production	Optimal Carryover	Available Supply	Trend
		India		
1968	81.6	3.0	78.6	80.7
1969	85.1	5.0	83.1	83.2
1970	91.7	10.0	86.7	85.8
1971	90.2	10.0	90.2	88.5
1972	86.6	5.5	91.1	91.2
1973	95.4	7.0	93.9	94.0
1974	86.7	1.0	92.7	96.9
1975		at probability level		99.9
		0.5 0.75 0.95		
	Carryover <	4.0 4.5 6.5		
		Africa		
1967		(1.0)		
1968	40.5	2.5	39.0	38.2
1969	41.3	3.0	40.8	39.3
1970	40.2	2.0	41.2	40.4
1971	40.9	1.0	41.9	41.5
1972	44.4	2.0	43.4	42.7
1973	37.1	0.0	39.1	43.9
1974	42.2	0.0	42.2	45.1
1975		at probability level		46.4
		0.5 0.75 0.95		
	Carryover <	1.0 1.5 3.0		

Table 2 shows how a carryover program would have affected the year to year variations of supplies of grain from domestic production. For comparison the smooth exponential trend of production is also listed. In India the relatively good harvests would have caused a gradual build up of stocks until 1972; 1972 and 1974 would have seen reductions in stocks. In Africa production variability

from trend was slight except for 1973 which was a disastrous year for grain production. Available reserves would have only partly made up for this unexpected shortfall. For India over the seven years 41.5 ton-years would have been held under the model we have specified. Africa would have held 10.5 ton-years.

The results from calculating optimal carryover for 1968 through 1974 given actual production levels were also used to calculate the probability distribution on optimal carryovers for 1975 conditional on the optimal 1974 carryover from Table 2. These probabilities differ from those of Table 1 because in that application supply in 1975 was based on 1970 supplies with uncertainty about the following years. For Table 2 the 1974 carryover is taken as given so the 1975 probability distribution of supply is simply the distribution for 1975 production plus the deterministic 1974 carryovers. It is interesting to compare these Table 2 results with those for India and Africa in Table 1. Differences are the result of less uncertainty embodied in the Table 2 experiment and also that for India 1974 carryovers were relatively high while for Africa they were low.

An International Cereal Insurance Program and Its Carryover Implications

The results presented in Table 1 demonstrate the value of reducing barriers to international flows of grain at short notice in terms of savings in carryover costs. We shall now consider a proposal of an international insurance program for providing security against grain production variability. We have made some calculations concerning an insurance arrangement which would guarantee that all shortfalls in grain production, in a country, below some specified percentage of the expected production in each year would be made up by insurance payments. Naturally in any actual situation the cutoff point for payments as well as the payments schedule and premiums would be a matter of negotiation. In our examples each region is insured fully against a grain harvest below 94 percent of their trend production. The difference between the actual harvest and the 94 percent level would be delivered by the insurer.

In Table 3 we show the insurance payments which would have been made from 1954 through 1973 under three grouping of countries and regions. These payments are computed as simply the sum of the payments to each country or region for each year. That is:

$$P_t = \sum_{k=1}^{K} P_{kt}, \text{ where } P_{kt} = .94\, \hat{X}_{kt} - X_{kt} \quad \text{iff} > 0 \quad \text{otherwise } P_{kt} = 0,$$

where t refers to years, k countries or regions, P refers to payments, $\hat{X}_{kt}$ is expected production and X_{kt} is actual product for a given region k in year t.

When only the developing regions are considered the insurance payments would have been quite small, the largest payment coming in 1966 when India had such a disastrous grain harvest. Both 1972, when the Far East and Latin America had poor crops and 1973, when it was Africa and the Near East which had below trend production, were major payment years. When the developed regions

TABLE 3

INSURANCE PAYMENTS TO SELECTED GROUPS OF COUNTRIES AND REGIONS, 1954-1973

(million tons)

Year	Developing Regions F.E. Disaggregated as in Table 1	Developing Regions No Disaggregate of F.E.	Disaggregated F.E. Developing + Developed Regions
1954	1.0	0.0	17.8
1955	1.5	0.0	1.5
1956	0.0	0.0	1.9
1957	5.0	0.2	9.8
1958	2.2	0.0	2.2
1959	1.3	0.0	2.1
1960	1.8	1.3	1.8
1961	0.0	0.0	7.5
1962	0.2	0.0	.2
1963	0.8	0.0	30.0
1964	0.0	0.0	11.6
1965	6.8	3.4	29.3
1966	9.4	5.5	9.4
1967	1.2	0.0	4.7
1968	0.0	0.0	0.0
1969	0.5	0.0	.5
1970	1.0	1.0	20.5
1971	0.0	0.0	0.0
1972	5.5	3.2	19.5
1973	8.7	8.7	8.7

are added to the insurance coverage the payment amounts rise dramatically. This is mostly the effect of the USSR which is a large grain producing area and has a history of periodic huge shortfalls in their grain production. The largest USSR shortfall over our data period was 1963 when the crop was only 75 percent of the trend value and would have generated an insurance payment of 29.2 million tons.

These payment totals in the past can be used to produce a probability

distribution of payment quantities in future years. By using the percentage payments for each country or region in the past to calculate the quantities they represent a percentage of, say, 1975 trend production, and then summing across regions a probability distribution for payments to the four developing regions in 1975 was derived. This was computed such that each quantity, $Q_t =$

$$\sum_k \left(.94 - \frac{X_{kt}}{\hat{X}_{kt}}\right) \hat{X}_{k75} \quad \text{iff} > 0 \quad \text{otherwise } Q_t = 0$$

was assigned equal probabilities of 1/T in a multinominal distribution, where $\hat{X}_{k75}$ is 1975 expected production, where T is the number of years of data. This distribution showed a probability of .65 that zero payments would be made, .80 that payments would be below 2.5 million tons, .95 that they would be below 7.5 million tons with the uppermost payment possibility in this distribution being 9.2 million tons.

Note that no specific international reserve is implied by this insurance scheme. Given some particular operating condition an optimal carryover amount could be calculated for the insurers on the basis of the stochastic nature of the demands they face. If either the agency had some access to a short notice world market in cereals or if some of the major producing countries or regions took the insurance agency position then optimal carryovers for the agency could be calculated using the models presented in this paper.

An advantage of the insurance approach to world co-operation is that it would not seriously interfere with the incentives of participating countries to encourage growth of production over time nor to operate their own carryover programs. Since the insurance payments would only be made in the case of very bad harvests relative to a long run trend, a country would not find much encouragement to reduce its production growth. Further, all stabilization above the insurance point would be left to the individual country or region. The insurance participants carryover decisions would be made on the basis of an altered probability distribution of supplies.

The area on the production probability distribution below the critical percentage would be shifted to exactly the critical insurance payment point. In our example all production possibilities below .94 of trend would be set equal to .94 $\hat{X}_t$. With the chance of major disasters eliminated by an outside source, optimal carryovers will obviously be less that with no such insurance.

Table 4 shows the results of the same experiment as reported in Table 1 but with the insurance policy in effect. Note the significant savings in the carryovers held by most countries and regions when these quantities are compared with those of Table 1. No insurance policy effects for the world as a whole were calculated because of the lack of an "outside" agency to act as the insurer.

The experiments for India and Africa with the hypothetical operation of an optimal carryover program over time was also repeated with an insurance policy in effect. These results are reported in Table 5. For India over the seven

TABLE 4

OPTIMAL CARRYOVERS FOR SELECTED COUNTRIES AND REGIONS, 1975
INSURANCE POLICY IN EFFECT

(million tons)

Country or Region	Probability Levels for Carryovers		
	0.5	0.75	0.95
A. Demand elasticity, η = -.10			
Burma	0.1	0.3	0.7
India	1.5	3.5	7.5
Indonesia	0.7	1.5	2.9
Pakistan-Bangladesh	0.3	1.5	2.7
Philippines	0.0	0.1	0.3
Thailand	0.6	1.2	2.1
Other Far East	0.3	0.7	1.5
Africa	0.0	1.0	3.0
Far East	2.0	5.0	10.0
Latin America	0.5	2.5	5.5
Near East	0.5	1.5	5.0
All Developing Regions	2.0	6.0	14.0
Europe	1.0	4.5	8.0
North America	3.0	10.0	28.0
Oceania	1.0	2.5	6.0
USSR	6.0	15.0	32.0
B. Demand elasticity, η = -.20			
India	0.0	1.0	3.5
Africa	0.0	0.5	2.0
Far East	0.0	0.0	5.0
Developing Regions	0.0	1.0	7.0
North America	0.0	4.5	16.5
USSR	1.0	8.5	23.5

year period insurance payments would have been made only in 1974 but the security of potential insurance would have reduced carryovers to 12.0 million ton years, a savings of 29.5 million ton years or around $400 million in storage costs and interest. For Africa payments would have been made in 1973 and 1974 which would have had very significant effect on available domestic supply, especially in 1973. There would have been no savings in carryovers for Africa. This follows because prior to the disaster of 1973 African grain production had only had one very slight shortfall of more than 6 percent, thus

TABLE 5

EFFECTS OF CARRYOVER PROGRAM ON AVAILABLE SUPPLY BASED ON ACTUAL PRODUCTION, INSURANCE POLICY IN EFFECT, INDIA AND AFRICA, 1968-1975

(million tons)

Year	Actual Production	Optimal Carryover	Insurance Payment	Available Supply
		India		
1968	81.6	0.5	0.0	81.1
1969	85.1	1.5	0.0	84.1
1970	91.7	5.0	0.0	88.2
1971	90.2	4.0	0.0	91.2
1972	86.6	0.0	0.0	90.2
1973	95.4	1.0	0.0	94.4
1974	86.7	0.0	4.3	92.0
1975		at probability levels		
		.5	.75	.95
	Carryover <	1.0	2.0	4.0
		Africa		
1968	40.5	2.5	0.0	39.5
1969	41.3	3.0	0.0	40.8
1970	40.2	2.0	0.0	41.2
1971	40.9	1.0	0.0	41.9
1972	44.4	2.0	0.0	43.4
1973	37.1	0.0	4.2	43.3
1974	42.2	0.0	1.2	43.4
1975		at probability level		
		0.5	0.75	0.95
	Carryover <	0.5	1.0	2.0

the calculations based on the insurance were essentially the same as those without insurance prior to 1973.

CONCLUDING COMMENTS

This paper has developed and illustrated the application of a specific procedure for calculation of optimal grain carryovers. We have incorporated information on production variability, demand elasticities and storage costs with restrictive assumptions of non-stochastic demand and simplified trade barriers in a mathematical optimization model. Our results, mainly for

developing regions of the world, show the major impact of variability in grain production on carryovers. This emphasizes the role of policy barriers and other restrictions to international trade which allows for offsetting production variability across region on the optimal reserves. We illustrated the potential impacts of a carryover program over time using India and Africa as examples. An insurance approach to world co-operation on food security was analyzed and found to have several useful characteristics and a major effect of reducing individual regions optimal carryovers while improving supply stability.

There is obviously ample opportunity in continuing this line of approach to world grain reserves, both in theoretic improvements and applications. Some of the most useful generalization of this model might include the incorporation of stochastic demands, non-independent production probability distributions over time and non-constant elastic demand curves. The development of the insurance policy concept involves a thorough consideration of the interaction between the optimal behavior of the insurance agency and the insured regions. Empirically, better estimates of demand elasticities, production distribution and especially appropriate trade barriers and regionalization are important before conclusive recommendations should be forthcoming.

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RESERVE STOCK GRAIN MODELS FOR THE WORLD, 1975-85

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ABSTRACT

This study provides a quantitative picture of an international grain reserve designed to effect reasonable stability in world grain prices. Various estimates of the magnitudes of reserve stocks required to achieve alternate price stabilization objectives in world grain markets with reliability are presented.

The empirical work of this study suggests that an international grain reserve of average size of 50-75 million tons could be operated for 1975-85 to hold annual grain price oscillations within a price range [+10 to -5 percent of trend] with a probability of 85-90 percent. These results and this paper should be viewed as a progress report.

THE GENERAL ANALYTICAL APPROACH

The focus of this paper is on stabilizing world grain prices through a reserve stock program [1,2]. The focus is on world grain prices and their stabilization not because world grain prices are necessarily the most critical factor to producers and consumers of grains and grain products, but because grain prices and changes in those prices best indicate the state of grain supplies in the world and changes in supply relative to demand. Thus, the focus of this study leads naturally and directly to a supply and demand type of analysis.

The general approach taken for developing estimates of reserve grain stocks and the associated probabilities for achieving different price stabilization objectives may be stated as follows. First a simple supply and demand model of the grain market under consideration was formulated. This supply and demand model then was used to determine market prices (i.e., those prices that satisfy equilibrium conditions). Disturbance factors were introduced into this basic model that randomly shift the demand and/or supply and generate as a result a probability distribution of market prices in a free market situation (i.e., with no intervention).

Second, different reserve stock decision rules were applied to the free market probability distribution of prices. The application of a given stocks rule to the free market distribution changes the distribution and generates a new probability distribution of prices associated with the particular stocks rule under discussion.

Finally, we analyzed the altered probability distribution to learn to what degree the variability in market prices is reduced or the price stabilization objective is achieved. Measures of the degree to which the price stabilization objective is achieved and the probabilities of achievement are presented in several forms. Estimates of the size of the reserve stock required to achieve a specific price stabilization objective with some probability are also presented for each decision rule [3].

No econometric work was undertaken to estimate the models mentioned above. Judgments were exercised in the selection of specific demand and supply parameters, but the specific parameters selected for use in this study are based on estimates commonly used in agricultural price analyses. In some cases alternative parameters were employed to test the sensitivity of the analysis to differently valued parameters. Thus, the models developed and employed in this

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[1] Brackets, [], denote footnotes at the bottom of each page. Underscored numbers in parentheses (_) refer to references listed at the end of this paper

[2] For a more elaborate discussion of this topic, see (2).

[3] For a different general approach, see (4).

analysis were conceived not to yield unique solutions, but to illustrate procedures for continuously investigating the problem as well as yielding estimates that illustrate the possible magnitudes of the grain reserve problem.

In our research, we were not trying to find unique answers to the related questions: what kind of a reserve stock program should we have and what should be its size? One reason we did not obtain such answers was lack of time and resources. But more importantly, there are probably no uniquely best answers to these questions. But we do come out with some estimates that illustrate the program magnitudes and characteristics that would be involved in a stabilization effect under alternative stocks rules and under different assumptions regarding price elasticities and size of beginning reserve stocks. We also develop a general analytical approach to an analysis of the reserve stock problem that we believe merits further development and refinement. Thus, from this research, policymakers can begin to learn the cost and quantity implications of an international reserve stock program, and research workers should find an approach and leads to further productive work on the reserve stock problem.

THE MODELS

Two specific models, a world grains model and a United States wheat model, were formulated and used to derive empirical estimates of the various magnitudes of a reserve stock program for the grains. Each of these specific models is a variation of the same basic model. This basic model is described immediately below, and the world and U. S. models are elaborated upon in the sections that follow.

The Basic Model

The basic model includes a demand function and a supply function for a single commodity. These functions include shifters of two kinds: systematic shifters that move the functions through time (i.e., growth factors) and disturbances that randomly shift the function back and forth. All variables except price and quantity are assumed to be exogenous to the model and are included either in the growth factors (e.g., systematic income and population growth effects on the demand and systematic technical change on the supply) or in the random disturbance (e.g., weather effect on yields, nonsystematic changes in trade policies, nonsystematic price effects of complements and substitutes).

Price is determined at the intersection of the demand and supply; it therefore fluctuates due to the systematic and random changes in the demand and supply. A stocks program is introduced that influences the price by adding to the supply when stocks are sold or by adding to the demand when stocks are acquired. An analysis of the activity of such a program is the core of this study. The complete basic model is described formally below. However, the nonprofessional reader can skip the rest of this section without a loss of continuity.

Demand function at time t

$$Y_t = [\phi(P_t) + e_{dt}] (1 + g_d)^t \tag{1}$$

where

Y_t = quantity demanded at time t,

P_t = price at time t,

$\phi(P_t)$ = mean of demand function at t = 0, $\phi'(P) > 0$,

e_{dt} = random disturbance term,

g_d = demand's rate of growth.

It is assumed that e_{dt} is distributed according to a known probability law, represented by $f_d(e_{dt})$, which is a probability mass function (in the case that e_{dt} is a discrete random variable) or a probability density function (if e_{dt} is continuous). It is assumed that $f_d(e_{dt})$ is identical for all t, that e_{dt} has zero mean and that any two disturbances of two periods, e_{dt} and $e_{dt'}$, are mutually independent.

All the exogenous factors that cause a systematic shifting of the demand function are assumed to be included in g_d (e.g., population and income effects), while all other exogenous determinants of the demand are included in e_d. (For example, if the demand includes a demand for export, the randomness might be due to weather effect on yield abroad, or e_d might be caused by unsystematic changes in prices of complements and substitutes, etc.)

Supply function at time t

$$X_t = [\Psi(P_{t-1}) + e_{st}] (1 + g_s)^t \tag{2}$$

where

X_t = quantity supplied from production at time t,

P_{t-1} = one-period-lagged price at time t,

$\Psi(P_{t-1})$ = mean of supply function at t = 0,

$\Psi'(P_{t-1})$ = > 0,

e_{st} = random disturbance term,

g_s = supply's rate of growth.

e_{st} is distributed according to a probability law represented by $f_s(e_{st})$, which is a probability mass function or a probability density function (if e_{st} is discrete or continuous, respectively). $f_s(e_{st})$ is identical for all t, and for any two periods t t', e_{st}, and e_{st} are mutually independent. In addition, e_{st} and e_{dt} are independent for all t t'.

As in the demand case, it is assumed that all of the exogenous factors of supply that are changed systematically with time are included in g_s (e.g.,

systematic technical change) and all other exogenous determinants of supply are included in the random disturbance e_s (e.g., weather effect on yields).

In summary, it is a simple "cobweb" model. For convenience, let us use the following notation:

$$\phi_t(P_t) \equiv \phi(P_t) \cdot (1 + g_d)^t$$
$$\Psi_t(P_{t-1}) \equiv \Psi(P_{t-1}) \cdot (1 + g_s)^t$$
$$\varepsilon_{dt} \equiv e_{dt} \cdot (1 + g_d)^t$$
$$\varepsilon_{st} \equiv e_{st} \cdot (1 + g_s)^t$$

and rewrite the demand and supply functions:

$$Y_t = \phi_t(P_t) + \varepsilon_{dt} \tag{1'}$$

$$X_t = \Psi_t(P_{t-1}) + \varepsilon_{st} \tag{2'}$$

Let us denote the stocks (i.e., program stocks in addition to working stocks) at the end of period t by C_t (the beginning stocks at t are C_{t-1}).

Given the lagged price, P_{t-1}, and the values of the random disturbances ε_{dt} and ε_{st} at time t, the price is determined by the equilibrium condition:

$$Y_t + C_t - C_{t-1} = X_t,$$

or

$$\phi_t(P_t) + \varepsilon_{dt} + \Delta_{ct} = \Psi_t(P_{t-1}) + \varepsilon_{st} \tag{3}$$

where

$\Delta_{ct} \equiv C_t - C_{t-1}$ is the change of stocks at t.

Define the "free market price" to be the equilibrium price where $\Delta_{ct} = 0$ and denote it by $\tilde{P}_t$.

$\tilde{P}_t$ is defined by

$$\phi_t(\tilde{P}_t) + \varepsilon_{dt} = \Psi_t(P_{t-1}) + \varepsilon_{st},$$

or

$$\tilde{P}_t = \phi_t^{-1} [\Psi_t(P_{t-1}) + \varepsilon_t] \tag{4}$$

where

ϕ_t^{-1} is the inverse demand function and $\varepsilon_t \equiv \varepsilon_{st} - \varepsilon_{dt}$ is the combined disturbance of supply and demand, ε_t is distributed according to a probability law represented by $f_t(\varepsilon_t)$, which is derived from $f_d(e_d)$, $f_s(e_s)$ and the definitions

of ε_{dt} and ε_{st} [4].

Equation (4) describes the "free market price" as a function of the lagged price P_{t-1} and the disturbance ε_t. Given $\tilde{P}_t$, beginning stocks C_{t-1} and carry-over stocks C_t, the price P_t is determined by the equilibrium condition (3).

The World Model

The different grains are close substitutes on the demand side and in some cases on the supply side too. Therefore, a model of the world grain market must include all the grains. For example, if wheat production falls short of anticipated utilization, users of wheat will begin to substitute rice and coarse grain for wheat, in which case the price rise of wheat is moderated as all grain prices move up. An effort to stabilize the price of one grain will affect the price of other grains via the substitution process. Ideally, it would be desirable to include explicitly and simultaneously the different categories of grains in the model, disaggregated as to countries and areas. However, methods and capacity of computation procedures prevented us from managing such a detailed model. Thus, a highly aggregative and simplified model was formulated. In the world model under consideration, *all grains* are considered as one great, aggregative commodity.

In this model, world trade is assumed to be conducted within one large market for a single aggregative commodity, grains, in which no important barriers to trade exist. All categories of grains move readily between and among areas in response to need as indicated by market prices.

The world demand for grains is assumed to be nonstochastic and sensitive to price (i.e., has slope). The form of the demand curve is linear. In the empirical analysis, we operated the model with two different assumed price elasticities of demand specified at average prices and quantities: -.1 and -.2 [5]. The world grain production is assumed to be stochastic and completely price inelastic. It grows at a constant annual rate of approximately 3 percent. This rate was estimated on the basis of a logarithmic trend that was fitted to the observations of world grain production for the period 1950-73. The probability distribution of production is assumed to be normal. The variance of it was estimated using the fluctuations around the trend. For each year in the projected period 1975-1985, then, world grain production could be of any magnitude with the associated probability in accordance with the probability distribution of production discussed above.

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[4] For example: if $e_d \sim (N(0,\sigma_d^2)$ and $e_s \sim N(0,\sigma_s^2)$ then $\varepsilon_t \sim N(0,\sigma_t^2)$, where $\sigma_t^2 \equiv (1 + g_d)^{2t} \sigma_d^2 + (1 + g_s)^{2t} \sigma_s^2$.

[5] The judgments that produced these price elasticity of demand assumptions were based on estimates presented for different categories of grain and different areas of the world in (1).

Each grain market model includes random disturbances, the probability distribution of which is assumed to be known. For each value of the disturbance, the model generates an equilibrium price. The probability distribution of the disturbances is then translated into a probability distribution of prices. This latter distribution we call the free market price distribution.

The free market price distribution is then changed, or modified, by applying some reserve stock rule to it. This change is effected by the acquisition or the release of stocks, thereby modifying the net supply of grain available to the market in the year in question. This in turn affects the market price and creates a new probability distribution of prices. Let us therefore look at one stock rule and the specific formulations that were applied to the market models [6].

The Bounded Price Rule

This simple rule states that insofar as stocks are available, market prices will not be permitted to oscillate outside a defined, or bounded, price range [7]. As used in this analysis, the rule states that whenever market price falls below the lower boundary of the price stabilization range, supplies must be acquired under the program in sufficient quantities to hold the price at the lower boundary. The rule also states that whenever market price rises above the upper boundary of the price stabilization range, supplies must be released, to the extent that they exist, to hold the price at the upper boundary. In practice, a grain price stabilization agency might deem it wise to start acquiring stocks before the market price had fallen to the lower boundary or to start releasing stocks before the market price had reached the upper boundary. But this kind of administrative flexibility is not investigated in this analysis.

Several specific formulations of the bounded price rule were investigated. A series of target prices for the years 1975-1985 was defined to be equal to the mean equilibrium prices, which in this analysis are always equal to 100. The boundaries of the price range are then defined in relation to the target prices of 100. We investigated four specific formulations of the bounded price rule:

1. Plus or minus 10 percent of the target price,
2. Plus or minus 20 percent of the target price,
3. Plus 10 percent and minus 5 percent of the target price,
4. A limitation on the volume of stocks held at all times to 3 percent of world production.

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[6] In this paper only the bounded price rule is presented. For a discussion of the price variability minimization rule, see (2)

[7] The "insofar as possible" clause might include operating funds as well as stocks, but we do not investigate a possible financial limitation in this analysis.

Countless other specific formulations of the bounded price rule might be investigated given the interest, time, and funds. Certainly, an agency that had the responsibility for administering a reserve stock program would want to investigate other specific formulations.

EMPIRICAL RESULTS: THE BOUNDED PRICE RULE

We will look at a specific formulation that involves a very low price elasticity of demand (- .1), no beginning reserve stocks, and a price stabilization range of plus or minus 10 percent of the target price 100. The application of this formulation of the bounded price rule reduces the price variation around the target price in 1975 from 27.4 percent in the free market situation to 20.4 in the stabilization situation [8]. By 1980 the variation around the target price is reduced to 15.4 percent under the stabilization program and remains at that approximate degree of variation through 1985 [9]. The probability of the market price remaining within the price stabilization range increases from 65 percent in 1975 to 81 percent in 1980 and 85 percent in 1985. The average reserve stock held in a particular year increases from some 9 million tons in 1975 to 57 million tons in 1985. The 1985 figure amounts to 3.2 percent of world grain production.

Two comparisons were made: a formulation with a bounded price range of plus or minus 20 percent of the target price of 100 and a formulation of plus 10 and minus 5 percent of the target price of 100. The wider bounded range allows the variation in the market price around the target price to increase as one might expect. A bounded price decision rule of plus or minus 20 percent of the target price seeks to achieve less in the way of price stabilization, and that is what it does. The bounded price decision rule, plus 10 and minus 5 percent, on the other hand, is a more restrictive rule, and it achieves more in the way of price stabilization. Variation around the target price is reduced to approximately 12 percent by 1985, compared with 19 percent for the plus or minus 20 percent rule, with 14 percent for the plus or minus 10 percent rule, and 27 percent for the free market. But the average cost of stabilization

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[8] To reduce the mass of data to be presented in this report, we consistently throughout the investigation ask the computer to provide results for only 3 years, 1975, 1980, and 1985.

[9] If these magnitudes of price variability seem inconsistent with the price stabilization boundaries of plus or minus 10 percent, remember that sufficient stocks are not always on hand to hold the free market price within the upper price boundary. The probability of market price being within the price stabilization boundaries of plus or minus 10 percent is 81 percent in 1980 and 85 percent in 1985.

goes up. The average reserve stock under the plus 10 minus 5 percent rule approximates 73 million tons in 1985 compared with average reserve stocks of 39 million tons under the plus or minus 20 percent rule, and 57 million tons under the plus or minus 10 percent rule.

If the price elasticity of demand for all grains does in fact approximate - .1 and if the beginning reserve stock is zero and the only criterion for acquiring or releasing stocks is the current price, then:

1. It is exceedingly difficult to reduce annual price variations around the price target below 10 percent.
2. But a careful formulation of the price stabilization boundaries (for example, plus 10, minus 5 percent) would permit an international stabilization program to reduce annual variations around the target price to close to 10 percent where the average reserve stock approaches 75 million tons.

If the stabilization effort begins with some stocks, say 20 million tons, then we see that market price variations around the target price decline significantly in 1975, which was not the case where there were no beginning reserve stocks. This, of course, is what we would expect to happen. The effect of the beginning reserve stocks is largely, but not entirely dissipated by 1980. If there were a large beginning reserve stock — a stock of 50 million tons — there would be a drastic reduction in the variation in market prices around the target price in 1975. But thereafter the variation increases, and the variation in 1985 with a beginning reserve stock of 50 million tons is not greatly different from that with a beginning reserve stock of 20 million tons, or for that matter, with a zero beginning reserve stock situation.

Our estimates indicate that some beginning reserve stock is desirable if a reduction in market price variability is sought for the immediate future, but that a very large beginning reserve stock achieves little in the way of long-run price stabilization results, hence should be avoided if program costs are an important consideration.

We have also investigated the consequences of limiting the reserve stock accumulation at all times to not more than 3 percent of total world grain production are investigated. The consequences are clearly unsatisfactory. The operation of a 3 percent limitation at all times restricts the accumulation of stocks of greater than 3 percent at certain times and thus has the effect of holding the average available reserve stock to such low levels, to 1.5 percent or less, that little is achieved in the way of price stabilization. The annual variation in market price around the target price in this formulation is close to 20 percent. If a limitation of this type were imposed upon the managers of an international stabilization program, it would certainly need to be greater than 3 percent of annual production, and some operational experience with a stabilization program should be gained before a rigid limitation on stock accumulation was made mandatory.

We have also explored the implications of the price elasticity of demand for grains in the world market being larger than - .1. As would be expected,

the price elasticity of demand has important implications for the whole issue of price stabilization. Increasing the measure of price elasticity from - .1 to - .2 reduces the market price variation around the target price in the free market situation from approximately 27 percent to 14 percent. Price variability in the free market is cut almost in half. And the application of a bounded price rule of plus or minus 10 percent of the target price, with a beginning stock of 20 million tons, reduces the annual variation around the target price to close to 9 percent for each of the years 1975, 1980, and 1985. To achieve this degree of price stabilization the average size of the reserve stock approximates 33 million tons in 1980 and 45 million tons in 1985. In sum, if we assume the price elasticity of demand for all grains is equal to - .2 then the need for a price stabilization program is greatly reduced and any degree of price stabilization is achieved more easily than it is with an assumed price elasticity of - .1.

We did not try to answer the question of what the true price elasticity of demand is for all grains in the world market. And the question will not be answered easily. But if it turns out from research efforts, or experience with international grain stabilization programs, that the true elasticity of demand for all grains is closer to - .2 than it is to - .1, then the difficulties and costs of operating an international grain stabilization program would not be unduly great. In a similar fashion, the pressures to operate such a stabilization program would not be great either. Relaxing the elasticity assumption reduces the acuteness of the whole problem. And a new set of issues and problems is opened up for the econometricians.

SOME POLICY AND ORGANIZATIONAL ISSUES

It is not the purpose of this study to recommend either for or against an international reserve stock program with the objective of price stabilization. That being the case we do not in this study make any recommendation about specific reserve stock decision rules. But we believe that the kind of information developed and presented in this study will prove helpful to policymakers in the concerned countries as to whether or not to embark upon reserve stock programs that seek to achieve international price stabilization for the grains. Indeed, this kind of information is essential to rational decision-making in this stabilization area. But policy and organizational issues exist that bear upon the question of international price stabilization for the grains that should be recognized and understood. We will explore some of those issues in this part.

But first we should like to make two points about the functioning of an international reserve stock program for the grains that are not always fully appreciated. First, grain prices would be allowed to vary under the operation of a reserve stock program of the type envisaged in this study, and thus perform their proper resource allocation role. But the extreme and disruptive amplitude of those price variations would be dampened down by the operation of the reserve stock program. Second, in the functioning of the world grain market, the stabilization objectives and stock decision rules would be known to all individuals, firms, and governments operating in that market. Hence, all

operators would know what to expect with regard to the future behavior of that market. The international grain market would become a more "fair game" in that all players wouod be playing under the same and known set of rules. The impact of a reserve stock program of the kind envisaged here on the international grain market would not be to weaken or destroy it. On the contrary, the market should be strengthened as it became increasingly stable and predictably more certain.

If the world market for grains were a free market in which there were no barriers to trade, then an international reserve stock program could operate most effectively and efficiently under a single international agency in which the reserve stocks were held in the surplus producing areas and were released to the deficit areas as needed. But the world market is not one large free market; further, the world market is fraught with uncertainty. This means that the countries most concerned with the maintenance of adequate domestic supplies and stable domestic prices will want those reserve stocks stored in, or readily available to, their respective countries. This suggests that if any international reserve stock program comes into being, it will be developed by the countries most concerned through some form of international agreement. In such an arrangement it seems likely that the management of each country's reserve stock would be undertaken by the country involved, but some form of coordinated or concerted action would be attempted. Further, we would expect that the concerned countries entering into such an arrangement might include both importers and exporters of grains, but for somewhat different reasons. The exporters might include Australia, Canada, Thailand, and the United States; the importers might invlude various European countries, Japan, and the city states such as Hong Kong and Singapore. In the long run the Soviet Union might find it to its advantage to enter into such an international stabilization arrangement, but recent history suggests that the Soviets would for a time at least rely upon imperfect information and chaotic conditions in the international grain markets to their advantage.

Given this kind of international organizational arrangement, the policy point that we wish to make is the following. For the arrangement to be effective, an agreement must be made first about the stabilization target price, or target price range, and second about the rules for acquiring and releasing stocks. If complete agreement does not exist by the country participants to the international arrangement on these points, the arrangement would meet with "rough sailing" and probably failure. Imagine what would happen if one country or group of countries sought to stabilize prices at a lower level than that of some other countries. The first group of countries would be continuously, or to the extent possible, releasing stocks to drive prices down, while the second group would be required to acquire unnecessarily large stocks to hold prices up to its price stabilization targets. The international stabilization effort would be working at cross purposes and would become an exercise in frustration and failure.

There are other program issues upon which agreement would have to be reached by the participating nations if the international stabilization program were to operate successfully. These issues include agreement on:

1. the maximum total stock to be acquired at any point in time,
2. the shares of that maximum to be held by each country participant, and
3. some means for coordinating stock acquisition and disposition actions by countries so that changes in stock positions in countries were deemed by the participants to be fair and equitable.

In sum, an international effort to stabilize grain prices through the operation of reserve stock programs in individual participating countries would require a high degree of coordination through an international secretariat to make the program operate smoothly and equitably.

The achievement of agreement on stabilization target prices and stocking rules is complicated by the fact that producer interests, which seek relatively high target prices, will in some participating countries be predominant, while in other countries consumer interests, which seek relatively low target prices, will be predominant. In still other countries, such as the United States, for example, the producer and consumer interests may be sufficiently evenly matched to make reaching an agreement within the country on a stabilization target price extremely difficult if not impossible.

This problem of reaching an agreement on the level of target price in a country such as the United States *may be* further complicated by the recent theory that the demand for grains has in recent years become more inelastic at lower prices, wherein consumers have more to gain and producers more to lose from price stabilization than formerly was the case (3, pp. 6-12). Whether this theoretical argument will be supported by empirical evidence remains to be seen. But if it is, the difficulty of reaching agreement on the level of grain target prices will be increased within a country such as the United States and among exporter and importer countries in an international agreement unless satisfactory ways are found for the consumer interests to compensate the producer interests in an international stabilization effort. In other words, given the argument that the demand for grain has become increasingly inelastic at high prices and increasingly elastic at low prices, consumer interests around the world may be forced to accept higher price stabilization targets than they currently anticipate or make some form of compensatory payments to producers to bring the producer interests into an international reserve stock program to stabilize world grain prices.

On the other hand, the configuration of the demand curve may not be changing as hypothesized above, the world could experience a series of bountiful harvests and a return to a surplus condition, and the fixed cost phenomenon in farming could squeeze the net income of grain producers to the point where they would be happy to participate in an international stabilization effort at a relatively low target price. But in this latter situation, would consumers have any strong interest in price stabilization? Probably not. Thus, we observe that, at any point in time, there is not likely to be a unity of interest about an international reserve stock program for the grains. The producer-consumer dichotomy of interests is a powerful one.

If the consumer-producer conflicts over price stabilization for the grains within countries and among countries are so severe that they preclude the

implementation of an international reserve stock program for the grains — what then? One option open to the United States, if it is able to resolve its own consumer-producer conflict over price stabilization, would be the implementation of a reserve stock program sufficiently large to stabilize world grain prices. This option is not out of the question, even though the full costs would be borne by the United States (or all the profits flow into the United States, because a certain combination of events could result in the reserve stock program earning a net profit). The average size of the reserve stock, as suggested by this analysis, would be smaller than the total stock of grain held by the United States in the late 1950's and early 1960's in connection with its farm price support programs, which incidentally served to stabilize world prices. We are not recommending this policy option, but it is a realistic option if the United States were determined to stabilize its own domestic grain, hence food, price level and still be integrated into the world grain market.

But for reasons of national price and diplomatic strategy it seens unlikely that the United States will pursue the course of action outlined above. What are the next points for consideration? First, the United States is not likely to withdraw from the international grain market; it needs that market to move its great surplus of grain and to earn foreign exchange. Second, there is no reason to believe that world grain price fluctuations will dampen down of their own accord over the next decade. In fact, there are two reasons why the amplitude of those fluctuations could increase: (1) the increased but sporadic entry of the two great state trading nations, the Soviet Union and the People's Republic of China, into the world market, and (2) the changing climate in the northern hemisphere and the *possibility* of increased variability in crop growing conditions associated with the changing climate. Third, there is no evidence to suggest that, and there is no logical reason why, private traders will increase their holdings of grain stocks in the future to moderate wide and unpredictable price fluctuations associated with unpredictable variations in world crop production and the trading policies of the state trading nations.

The logical argument in support of this last point follows:

> "....the profit motive will guide grain into consumption or storage according to facts presently known, beyond which the most probable will be assumed — meaning normal or average production. It amounts to a contradiction in terms to ask the marketplace to dictate stocks accumulation according to the lesser probability of some future crop failure. To be sure, some participants may premise the purchase of futures contracts upon the chance that crops not yet planted will fail, but likewise others will sell in anticipation of bumper crops. Unless market psychology is persistently biased on the pessimistic or optimistic side of matters, the market must reflect the known and most probable. There are no profits to be earned by consistently investing in improbable prospects — and crop failures, lacking regularity and predictability as they do, are not commercial propositions until such time as information becomes available to diminish the high probability of an average crop If crop yields are taken to be stochastic (after due allowance

for trends and control measures) then the most profitable assumption is that yields in any future year will be normal (3, pp. 1-2).

Thus, in our view, world grain price variability seems likely to be as great, or greater, in the next decade than it was in the last. The problem of price instability in the grains, with the appropriate lags in animal product prices, is not going away by itself, nor will it be wished away. In this context what are the policy prospects in the United States? *They are more of the same.* In periods of sharply rising farm and food prices, policy actions in the United States are likely to include:

1. the imposition of ceiling prices on food products,
2. the further expansion of food programs to assist the poor (e.g., the food stamp plan),
3. the use of export limitations of both formal and informal types, and
4. sporadic attacks on the monopolistic practices of big business and big labor in the food industries.

In periods of falling farm prices and stable to declining food prices, policy actions in the United States are likely to include:

1. efforts to maintain or raise commodity loan rates,
2. the imposition of production controls,
3. the expansion of foreign food aid programs, and
4. the making of supplemental income payments to medium and small sized commercial farmers.

The basic policy issue confronting consumers and producers of grain products specifically, and food products in general, in the United States may be formulated as follows. Are those interests content to leave the world grain price instability problem untouched and deal with its domestic symptoms in the future in essentially the same ways as they have been doing in the past 10 years? Or do they wish to initiate an international grain reserve program with the capacity to effect some reasonable stability in international grain prices and thus reduce the pressure to implement countervailing, or compensating, domestic programs? This is the basic policy issue confronting consumers and producers of food in the United States in the foreseeable future.

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GRAIN RESERVES AND THE U.S. ECONOMY: A POLICY PERSPECTIVE

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Abstract: Domestic grain reserves seem potentially useful for meeting uncertain foreign demand, for improving stability of the livestock industries, for reducing risk and increasing efficiency in grain production, and for moderating consumers' dissatisfaction with unstable food prices. Information is needed on the benefits and costs of reserve programs of different scope and design. Researchable problems range from narrow questions to systems analyses of the feed-livestock sector. In a still broader sense, reserve stocks might be considered as one element of an integrated food and agricultural policy for the nation.

The question of grain reserves for the U.S. is not new. More than 25 years ago, economists discussed stabilization of farm markets and welfare gains that might result; reserve stocks were one but not the only stabilizing device considered. Almost 50 years ago, the Federal Farm Board launched the first of a seldom-interrupted series of programs that resulted in government control of stocks of farm commodities. The primary objective of such programs was to support farm prices and income. Though the programs usually brought some stability to farm markets, reserve stocks and price stability were mainly by-products of the support programs.

The surge of demand that began in 1972 sharply increased farm prices to well above support levels and greatly reduced stocks owned or financed by government. A change in farm legislation in 1973 increased emphasis on direct payments and decreased emphasis on price support in the event declining prices should bring farm programs for grains into play once again. Meanwhile, grain prices have gyrated widely under the impact of large changes in export demand and weather. Food aid for poor countries has become a more important concern than ever before. A reserve stock policy for grains in the U.S. as a means of stabilizing markets and of facilitating food aid has emerged as a national issue in its own right, free--for the time being, at least--of domination by price and income support objectives.

THE PROBLEMATIC SITUATION, NARROWLY CONSTRUED

The grain reserves policy issue exists in a setting that reveals certain potential benefits of such a policy, certain costs, and conflict about the desirability of possible outcomes. The U.S. expects its food sector to feed the domestic population well, to earn foreign exchange through exports so that

other goods and services can be imported, and to supply at least some food aid for poor countries. It expects these functions to be performed smoothly and efficiently. Grains are central to the food economy, for they are the feed base for the livestock industries that produce meat, dairy, and poultry products, and grains are, collectively, the leading agricultural export.

Let me make a positive statement that depends both on several propositions whose accuracy has not yet been established and on value judgments. The statement is this: Grain stocks voluntarily carried by the trade (producers, grain handlers, processors, etc.) will be inadequate in the sense that the nation's objectives for its food sector would be better met by a well-managed grain reserve program.

What benefits might a domestic grain reserve program have over free-market behavior? One might point to the increased importance of commercial exports as a share of total utilization and to the high, unpredictable variability of export demand. This situation seems likely to induce domestic instability that conventional market mechanisms cannot satisfactorily curb. One might further argue that dependable supplies and stable prices in the U.S. will encourage the long-range development of commercial grain exports, which both the nation and producers want.

Foreign food aid is in addition to commercial exports. Year-to-year needs are likely to be highly erratic. Supplying aid only when grain can be readily spared from current production is not a good solution; neither is accepting the domestic instability that uneven aid shipments would induce. Reserve stocks seem called for. Though an international reserve might be carried, a portion of it probably would be located in the U.S. Separation of food aid reserves, which may be internationally controlled and financed, from commercial reserves to serve the national interest is a strategy deserving considerations.

Another possible benefit of grain reserves is more stable output and prices in the livestock industries. Instability of livestock production induced by variable supplies and prices of feed grains surely causes inefficient use of fixed resources, income variability for livestock farmers and processing firms, and unstable employment of labor. It seems unlikely that all of these costs somehow find full expression in market incentives for private grain storage.

Instability of food prices is itself a disutility to consumers. A related consequence of instability probably is an impetus to general inflation. In a ratchet-like manner, upswings in food prices may tend to increase industrial wages through cost-of-living escalators in labor contracts.

Two other possible benefits of stable grain prices are the utility of reduced risk to grain producers and more efficient grain production resulting from less uncertainty. These propositions are surprisingly complex and slippery. Total income of producers from sale of, say, wheat may be more stable when changes in yield per acre are permitted to cause price variation than when price is stabilized. Stability of income may be more significant for risk and resource allocation in wheat production than is stability of

price. Stability of total producer income is not the whole answer, however, for yields per acre on different farms are not equal in variability, nor are they perfectly correlated. In general, the effects of price instability on risk and resource allocation probably are different for supply-induced instability than for demand-induced instability, and effects are not identical for all producers.

The final possible benefit of grain reserves is protection in the case of rare national emergencies--for example, a war or great drought.

The potential benefits of grain reserves would entail costs, principally in the form of carrying charges and administration. The more ambitious the reserve program--pursuing greater benefits--the more the program is likely to cost. An important point here is that the grain trade would be likely to carry only low working stocks if the government operated a reserve program. Probably the trade would carry some contingency stocks if there were no reserve program. The government's cost for a reserve program can therefore be expected to include some costs that the private sector otherwise would bear.

It is not possible for an economist or any other individual to weigh objectively for all the people the various benefits and costs of a grain reserve policy. Research can, however, go a long way to identify available alternatives and to set forth, often in quantitative terms, probable benefits and costs and to whom they accrue. Economic policy decisions are made through a political process which, though not exactly avid for facts and analyses, usually works better when participants bring information to their task.

QUESTIONS FOR RESEARCH

To this point, I have presented a conventionally structured, if rather loose, outline of the problematic situation representing the grain reserves policy issue. I shall elaborate upon it later, but I want to pause here to identify some important research questions. I shall not try to frame them rigorously.

One version of a key question is the following: What degree of stability can be expected from different levels of reserve stocks and different storage strategies? How adequate would different reserve programs be for dealing with domestically generated exogenous shocks to the system? With instability arising in the commercial export market? Through food aid? With all destabilizing influences together?

Answers to these questions should be compared with behavior expected in the absence of a reserve stock policy. A difficulty here is that little empirical evidence is available on the amounts of grain stocks the private sector would voluntarily carry, because government-held stocks have much influenced private grain storage for most of the past two decades.

The next obvious question concerns the costs of programs of different scale and design, together with estimates of the portion of program costs that would be incurred by the trade in the absence of a reserve program.

Important benefits accruing to different groups appear to be estimatable. For example, effects on grain producers' average prices and income can be shown, at least for the case where increased price stability does not cause shifts of supply functions for grains. Effects on stability of prices, incomes, production, utilization in various forms, and the like can be described. Apparently, it will be difficult to evaluate quantitatively such hypothesized benefits as long-term export expansion or increased efficiency in the livestock industries. Though stabilization effects can be described, I see little prospect of placing values on consequent changes in personal utilities of consumers, producers, and other participants in the system.

The research is interesting and challenging because of the actuarial questions associated with estimating the adequacy of different levels of stocks, the strategies that might be used in deciding when to accumulate and liquidate stocks, the realization of benefits and costs over time rather than at a point in time, and the complexity of the grain-livestock system itself. Grain prices affect grain and livestock production and are recursively influenced by such production. The individual grains are substitutable for each other to varying degrees in both production and utilization. There are important differences between short-term and long-term responses to prices, and expectations can cause stock holdings to respond perversely to price changes. Indeed, it seems likely that demand functions for private storage will themselves be influenced by storage rules adopted for a government reserve stock program.

As the foregoing suggests, there is much scope for models and methods drawn from econometrics and operations research. Researchable problems range from narrow questions that can be intensively studied to systems analyses of considerable generality. Reserve stock questions illustrate the need for detailed and accurate models of the agricultural sector capable of analyzing a wide range of policy problems concerning exports, reserves, production adjustments, impacts of energy costs, and the like.

ELABORATION OF THE POLICY ISSUE

I now return to the earlier discussion of the grain reserve policy issue. The rather narrow and antiseptic treatment of the topic to this point fails to identify some important economic ramifications and significant political positions.

It is possible that the U.S. food economy of the next decade will be so nicely in balance that neither shortages nor surpluses will be deemed to exist by producers or consumers. It is perhaps more likely either that strong commercial export demand will cause consumers to consider that domestic shortages exist or that rising food production coupled with moderate export demand will cause farmers to say that grain surpluses have returned. In the

shortage situation, strong pressures would exist for export controls; in the surplus situation, price support, direct payments, and production control might reappear on the scene.

Thus, it is readily conceivable that a reserve stock policy will be in effect jointly with an export control policy, a farm income support policy, or both. Export controls, price supports, production control, and direct payments are all potential instruments of stabilization as well as instruments serving other purposes. For example, reserve stocks might be the first line of defense against instability, with export control at one extreme and production control at the other extreme serving as second lines of defense. A comprehensive food and agriculture policy flexible enough to cope with a highly uncertain future would consist of a package of complementary programs, including but not limited to reserve stocks. Research on reserve stocks might well include complementarities with other types of programs and might treat reserve stocks as only one of several stabilizing devices.

Another important complementarity exists between domestic reserve stock policy and international reserve stock policy. Several combinations of domestic and foreign reserves for food aid are possible. U.S. policy regarding domestic reserves and commercial export management might have a strong influence on reserve stock policies and buying practices--especially contract purchases--of other countries.

The reserve stock issue exists in a setting much influenced by old controversies about farm policy, strong political feelings about the functions and integrity of government, the usual clashes of interests of different economic groups, and sharply different valuations about food aid and U.S. responsibilities abroad. Many grain producers and the nation's largest farm organization oppose the reserve stock idea because they do not favor government intervention in markets, believe that reserve stocks would be used to placate consumers at the expense of farmers, and think that reserves would reduce average producer prices. It is not clear what researchers might do on essentially political questions, but researchers should be aware of them.

Who should control reserve stocks is another concern. Ownership and control are related to stock location and the power of decision over stock accumulation and liquidation. Perhaps the principal question is who is to gain when changing circumstances raise prices and call for release of stocks.

Storage rules--the guidelines for pricing and managing stocks--are more important than their obvious function in a reserve stock program might suggest. The real possibility of manipulation for political or monetary gain and the current suspicion of government put a high premium on objective rules for stock management. Also, it seems important that the market be able to anticipate stock management transactions so that private actions will be efficiently meshed with reserve stock operations.

CONCLUDING COMMENTS

Like most economic policy issues, the grain reserves problem is complex, overlaps policies on other topics, involves competing values of individuals and interest groups, and is infused with political considerations. At the center of the problematic situation, however, are several questions that only quantitative research can answer and that seem amenable to such research. Some specific questions can be separated out and studied successfully in a narrow context. The larger questions require a systems approach, for prices, production, utilization, and stocks react upon each other over time in a complex economic sector highly subject to external shocks. But quantitative study can answer certain questions only partially or not at all. Finally, alternative reserve strategies are not self-evident; they need to be identified and considered jointly with other elements of comprehensive food policy.

AGRIMOD:

A SIMULATION MODEL FOR THE ANALYSIS OF U.S. FOOD POLICIES*

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ABSTRACT

AGRIMOD is a dynamic simulation model that provides a framework for evaluating the effects of agricultural and energy policies on U.S. food production and consumption. The model can be used to identify potential crises in the availability of natural resources and to indicate the circumstances of their occurrence over a 10-20 year period. Of particular significance is its capability of handling policy questions relating to the management of grain stockpiles or reserves. The basic version of the model has been completed and has been tested in terms of the historical scenario for 1955-1970.

1. INTRODUCTION

Abundance of food and energy were once taken for granted in developed countries. In recent years, however, world events have led to a reappraisal of the situation. The environmental and energy crises have directed attention to the limited availability of natural resources, to wasteful practices, and to the detrimental effects of pollution. The technological revolution, which has enabled rapid economic growth to occur in the developed countries, has had an important effect in less developed countries - a marked reduction in death rates and, as a result, a high rate of population growth. In the fifties and sixties food production increased at a rate just slightly faster than that of population growth (2.8% vs. 2.6% for the developing countries), resulting in a very slight improvement in per capita production and in the average diet. Recent analyses, however, indicate that energy constraints, non-renewable resource scarcities, and a possible change in climate may actually cause a long term deterioration in the world food situation (2). Spectres of such food scarcity necessitate a critical look at commodity reserves programs - their function as both a mechanism for smoothing commodity market oscillations, and as a means of building a stable buffer for use in the event of domestic or international shortages.

The events of the last four years in the world food market have created additional constraints that U.S. policy makers must take into account in determining U.S. agricultural policy (1). The complexity of the interrelationships affecting food supply and the strong impact that farm policies may have

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on various sectors of the national economy have already indicated the need for developing a versatile, but comprehensive, model of the U.S. food production system that can assist policy makers in assessing the impacts of alternative policies.

AGRIMOD (Agricultural Model) is designed to provide the framework for:

a) Analyzing the effects of alternative national policies on the food supply;

b) Identifying the impact of possible natural resource and energy constraints on the food supply and on prices;

c) Evaluating the effects of grain reserves management on availability and price;

d) Assessing the long term impacts of policies on consumption (diets and nutrition).

The scope of the model is restricted to the consideration of *national* impacts of national and selected regional policies, and selected international impacts of national policies. The analysis of regional or rural development policies was taken to be outside the scope of this work; a large number of such models are already in existence.

2. MODEL SPECIFICATIONS

The original specifications (July 1974) placed emphasis on the analysis of the impacts of possible energy constraints and of probable technological change. The desire to accommodate technological change explicitly in conjunction with the 15-20 year horizon led to a dynamic model with a structure that adapts to endogenously determined conditions.

The basic resources considered are land, water, energy, minerals, and capital. The model includes mechanisms for evaluating the impact of overall climatic change and of crop/location specific weather and pesticide effects on yields. The time increment used in the model is one year, i.e., an annual production cycle is considered. However, within each year a multistage sequence of events is used to model the biological and economic interactions that occur in the food production chain.

Finally, the degree of disaggregation was established by the types of policy questions that would be analyzed using the model. Typical examples of such policies are: land regulations, government investment in land improvement (irrigation, drainage), environmental regulations on the use of fertilizer and pesticides, support prices and price ceilings, selective commodity taxes, grain reserves and other stockpile management policies, as well as such questions as world food reserve policies, and Food for Peace commitments.

3. MODEL STRUCTURE

The dynamic model that has been developed consists of seventeen (17) sub-models fully integrated in four major sectors connected by three markets. The four sectors are: 1) the pre-production sector, 2) the crop production sector, 3) the food supply sector, and 4) the food consumption sector. Goods move between sectors through the markets. The three markets are: the farm input market, the farm output or crop market, and the retail food - or consumption - market. Information and material flows integrate the components of the model. The simplified diagram of the annual food production cycle (Fig. 1) shows clearly the multistage sequence of events within one year and the interrelationship between sectors and markets. A brief description of each of the sub-models follows.

3.1 The Pre-Production Sector

This sector consists of three sub-models; its purpose is to allocate investments, update land use capital stocks, and generate the endogenously determined supply curves for several inputs to crop production.

3.1.1 The Investment Model (1)*

Three types of investment in agriculture are considered: government investment, private monetized investment, and private non-monetized investment. Total monetized investment in agriculture is keyed to total national investment, which is exogenous. Investment by the government is affected by policy variables; it goes mainly to land improvement, including investment in irrigation and drainage (or, more generally, in water resource management), and to research (including information dissemination). Monetized private investment is used to improve land and to increase capital stocks such as machinery, structures, etc. Part of the investment goes into industries that provide inputs to agriculture, e.g., the fertilizer industry. Non-monetized private investment is used for cropland and grazing land improvement. A major component of this submodel is the determination of the investment in the development of new irrigated cropland.

3.1.2 The Fertilizer Industry Model (2)

A dynamic model of the fertilizer industry has been developed. It accepts as inputs quantities and prices (supply curves) of raw materials and produces supply curves for the three basic nutrients: Nitrogen, Phosphate, and Potash. Investment in the fertilizer industry is used to increase plant capacity. A variety of technologies can be used to produce the three nutrients; the choice of technologies depends on the relative costs of the primary inputs, and on policy variables. Changes in technology are constrained by the non-convertibility of existing plants and equipment. The structure of the fertilizer model is shown in Figure 2.

*The number in parenthesis indicates the block in Figure 1.

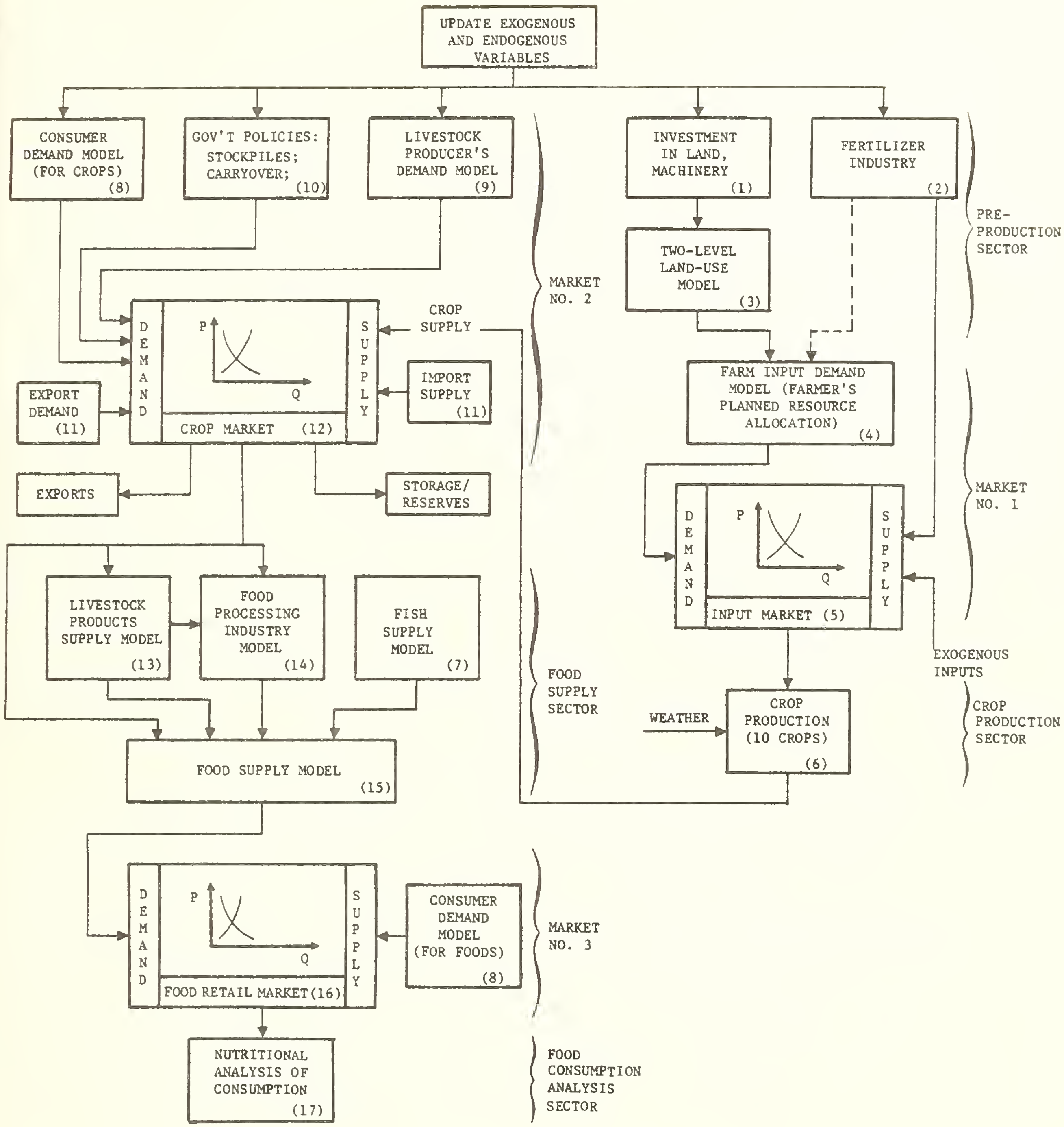

Fig. 1. Simplified Diagram of AGRIMOD.

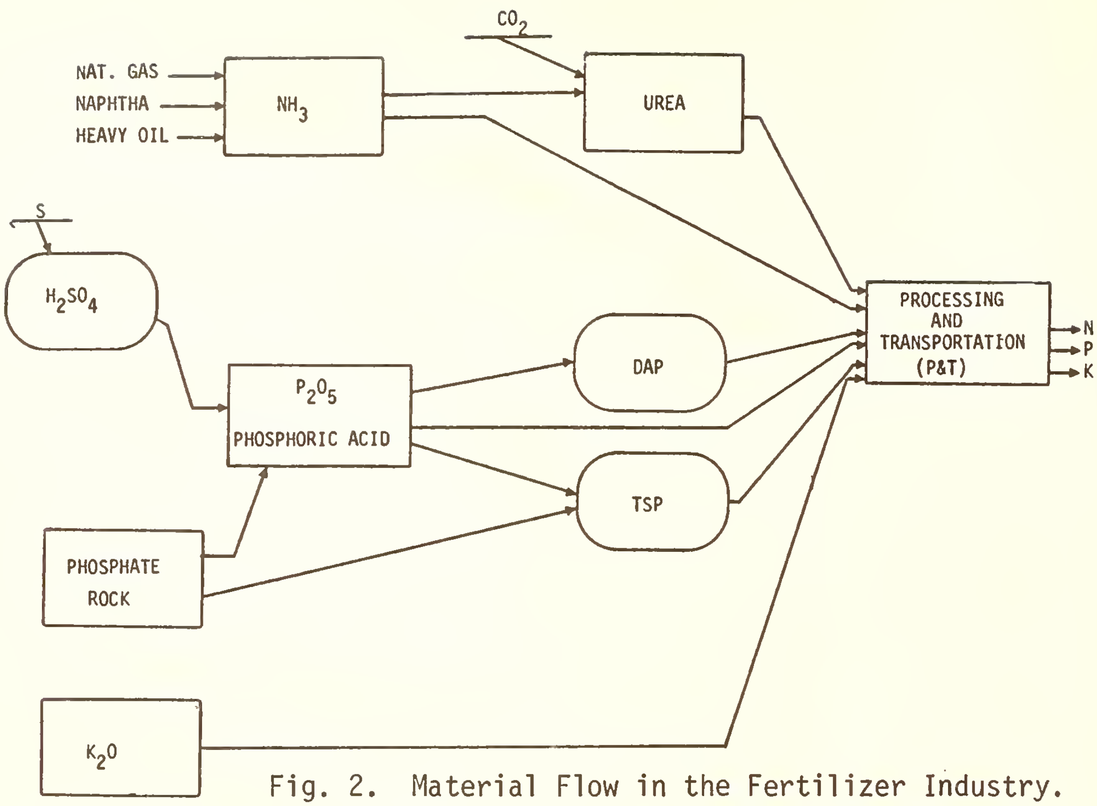

Fig. 2. Material Flow in the Fertilizer Industry.

3.1.3 The Land Model (3)

This is a two level model. At the higher level, thirteen types of land are considered, grouped into three classes:

a) Cropland in Use: Arid cropland, humid cropland;

b) Grazing Land: Improved arid pasture, Unimproved arid pasture, Improved humid pasture, Unimproved humid pasture, Forest land used for grazing;

c) Land Not Used for Food Production: Unavailable land (urbanized, etc.), Forest land not used for grazing, Arid land suitable for pasture, Humid land suitable for pasture, Unused arid cropland, Unused humid cropland.

Each type of land is modeled as a capital stock variable: land of type i in year k is equal to the same type of land in year $k-1$ plus any shifts of land from other categories minus any shifts of land to other categories. Land upgrading occurs through investment - both monetized and non-monetized; land degradation occurs through a variety of mechanisms such as lack of maintenance of previous improvements, urbanization, etc. It should be noted that a double accounting system is used for land: actual acres and equivalent standard acres. It is assumed that as more land is brought into production, the multiplier that converts actual acres to standard acres decreases. On the other hand, some of

the most productive land is lost to urbanization.*

The second level contains the crop-location specific disaggregation of arid and humid cropland. The following 10 distinct commodity producing regions are used: they cover 97% of the land used for agricultural production in the U.S.

1. Corn-soybeans-hay
2. Corn-soybeans-wheat-feedgrains-hay
3. Wheat-feedgrains-hay
4. Cotton-corn-soybeans
5. Potatoes
6. Sugar
7. Fruits and vegetables
8. Rice
9. Wheat-feedgrains-cotton
10. Corn-hay

The above classification permits substitution of crops while preserving climatic and soil constraints on the extent of such substitutions.

Another feature of the land model is that it incorporates both improved and unimproved pasture. This feature permits the analysis of such practices as the application of fertilizer to pasture.

3.2 The Farm Input Market

This part of the model contains two submodels: the farm input demand model and the model of the supply-demand interaction for inputs to crop production.

3.2.1 The Farm Input Demand Model (4)

This is fundamentally an optimal resource allocation model. The optimum allocation of land, machinery, and fertilizer for each crop in each region is determined on the basis of endogenously computed expected prices for the inputs of production (costs) and for the outputs (the ten crops), the cropland available in each one of the ten crop producing regions, the crop-specific machinery capital stock, and the crop production functions.** The mathematical form is that of a nonlinear programming problem subject to linear inequality constraints. A generalized reduced gradient algorithm is used for the determination of the optimum allocation. The results are converted into demand functions

*A new land data base that will increase substantially the model's versatility is now being implemented; all land types are disaggregated into 10 geographical regions.

**Generalized forms of the Mitscherlich-Baule-Spillman production functions are used.

that are then aggregated into total demands for each type of nutrient, for fuel, for electricity, for labor, and for irrigation water. These demand curves are the ones used in the supply-demand interation for inputs.

3.2.2 The Market for Inputs to Crop Production (5)

The market is modeled as a constrained supply-demand interaction through which equilibrium prices and quantities are established. The supply curves either have been generated in the Pre-Production Sector or are exogenous. The demands are generated in the Farm Input Demand Model. Only non-capital-stock inputs are considered; purchases of farm machinery, pumps, etc. are determined in the investment model. The quantities traded at this market are: fertilizers (three nutrients), pesticides, fuel for machinery, and electricity. Labor, irrigation water, and seed enter as costs; there are several constraints that relate machinery utilization, fertilizer use, labor, and irrigation water. An iterative Regula Falsi algorithm is used for establishing equilibrium prices and quantities.

3.3 The Crop Production Sector

This sector contains the crop production model that determines realized production on the basis of actual inputs.

3.3.1 The Crop Production Model (6)

In this model the factors of production determined at the farm input market are inserted in the crop production functions, and the nominal level of production of each crop in each region is determined. The nominal values are modified to reflect the impacts of weather and of climatic change (exogenous variables). The output of this model is the total annual production of:

1. Wheat
2. Rice
3. Corn
4. Feedgrains (Barley, Oats, Sorghum)
5. Hay
6. Soybeans
7. Potatoes
8. Sugar (Beets and Cane)
9. Fruits and Vegetables
10. Cotton

Cotton has been included because of the strong impact this crop has on land use, pesticide use, and agricultural policy in general.

3.4 The Crop Market

This is by far the most complex part of AGRIMOD; it is essentially the wholesale farm commodities market. To the annual crop production are added carryovers from previous years and imports; losses incurred during transportation and storage are subtracted. The resulting quantities are the ten basic supply curves. Aggregate demand curves for each one of these crops are generated from livestock models, from the food consumption sector, and from the export model. Many of the government policies that can be analyzed using AGRIMOD are introduced either as demand functions or in the form of constraints that modify the crop supply curves or the crop disposition.

3.4.1 The Consumer Demand Model (8)

This model is used twice in the program: once to determine demand functions for the food commodities and once to determine demand curves for crops. The demand for each commodity is a nonlinear function of its price, the prices of other commodities that can be used as substitutes, and disposable income. The elasticities and cross-elasticities of demand are entered as parameters. These demands are converted to demands for crops by combining the demands for products derived from the same crop (e.g., wheat bread and flour demand and other wheat products demand are combined and expressed in the form of demand for wheat grain).

3.4.2 The Livestock Producer's Demand Model (9)

Five types of livestock are considered: beef cattle, dairy cattle, hogs, poultry-layers, and poultry-broilers. Each type has its own population dynamics equations that are expressed in terms of cohorts; production functions* are associated with each cohort. The beef and dairy cattle models are coupled and so are the two poultry models. The herds or flocks are treated as capital stocks.

The inputs to the livestock sector are three types of feeds:

a) grain (feedgrains, corn, and wheat)

b) high protein (soybean meal, cottonseed meal, and fishmeal)

c) roughages (hay and pasture).

The livestock producer has to determine what the slaughter rates (or his production) should be, and he should establish on that basis his demand for feed. The complexity arises from the fact that some of the products (e.g.,wheat soybeans) are both intermediate (conversion of grain into meat) and final goods (grain to flour). The method chosen to model this problem is to formulate it as an optimal control problem in which the livestock producer (a) determines the optimal slaughter rates (or level of production), and (b) establishes the optimal demand functions that correspond to the desired herd size and

*A new class of production functions that includes the desirable features of both the Mitscherlich-Baule-Spillman and the Cobb-Douglas functions is utilized.

composition. The objective function for determining slaughter rates models the trade-off between current returns (annual production) and future returns subject to investment constraints. The optimization is carried out in two steps. First the optimum number of animals slaughtered from each cohort is determined and then the optimum demand curves for the three types (whenever appropriate) of feed are generated. Finally, demand curves for wheat, corn, feedgrains, soybeans, and hay are determined.

3.4.3 The Government Policies, Stockpiles, and Carryover Model (10)

Some of the most critical issues facing policy makers are those that deal with stockpiles in general and grain reserves in particular. This submodel is designed to accept as inputs a wide variety of alternative policies and regulations. Since policy objectives regarding grain reserves are often in conflict, it is not possible to create one model that could handle all possibilities. Instead, a set of alternative structures that correspond to different objectives and different mechanisms for achieving them is being implemented. For example, in the past, one objective of government stockpiling policies was price stabilization and maintenance of farm incomes. One mechanism for achieving this objective was the introduction of price triggers. This particular structure has been implemented; a graphical description of the model is shown in Fig. 3, where the effects of commercial reserves or carryover have been omitted.

If the objective is to accumulate specified grain reserves over a period of years, then a direct price dependent (or independent) Government demand can be introduced. Other mechanisms that require minor modifications for implementation are quantity triggers and various combinations of the above.

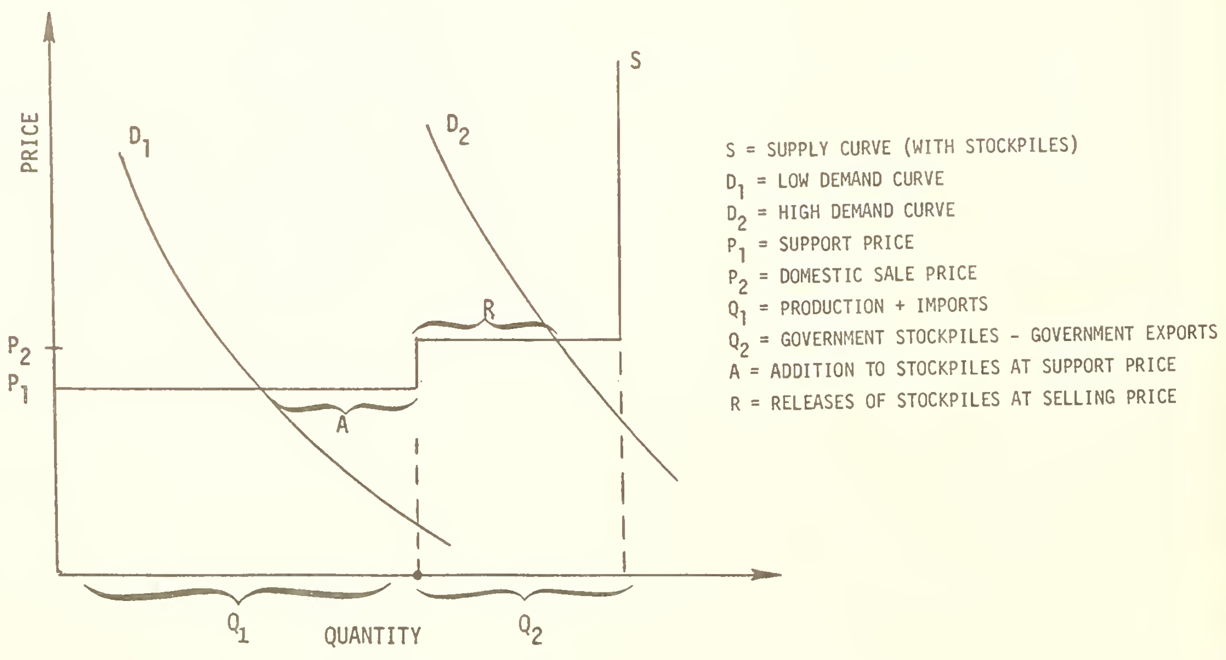

Fig. 3. Simplified Example of Price Trigger Reserve Model

The commercial carryover model is basically a storage model. A pipeline effect that differs for each crop determines the minimum level of carryover. The actual level is in part affected by a term that is inversely proportional to the size of government reserves; however, perturbations about this level are taken to be proportional to price driven changes in government reserves.

Food for Peace and other direct government exports can be handled in either one of two ways: as disposition of surpluses to be obtained from existing stockpiles subject to a minimum depletion constraint, or as direct demand that enters the supply-demand interaction and thus affects prices.

Further work on the modeling of grain reserves is planned in the course of carrying out specific policy analyses.

3.4.4 The Export/Import Model (11)

This is a simple model in which demand for exports is computed on the basis of exogenous variables. Imports are exogenous except for sugar, where the level of imports is obtained by considering a target price.

3.4.5 The Crop Market (12)

The various components of the demand for each crop are combined to form a vector demand function for the ten crops. The supply curves are constructed endogenously, based on the current price support levels, reserves policies, import regulations, and commercial carryover practices. A generalized reduced gradient (GRG) algorithm, modified to handle problems with kinks in the objective function, is used to determine prices and the actual disposition of the crops.

3.5 The Food Supply Sector

This sector consists of four submodels; included in them is the Fish Supply model. Its inclusion is necessary because of the substitution effects in food consumption and also because of the use of fishmeal in the high protein component of commercial feed.

3.5.1 The Fish Supply Model (7)

A simple model of the U.S. fishing industry has been developed. It relates the catch to the fishing effort which is a function of the capital stock (ships) and the number of days per year that the ships are engaged in fishing, and to the fish population. The domestic fishing effort is determined endogenously, while the foreign fishing effort is exogenous. Fish imports are added to the domestic fish catch. The supply is decomposed into fish for direct human consumption and into fishmeal that is used either for export or in animal feed.

3.5.2 The Livestock Products Supply Model (13)

Following the supply-demand interaction, the livestock producer allocates the purchased feed among the various cohorts in agreement with the demand

functions. If the purchased feed is inadequate, then a series of adjustments are made in the rations, in the number of animals that go to feedlots, and in the slaughter rates. Another control variable is the time of slaughter or, alternatively, the weight of the animal at the time of slaughter. The output of each livestock model is the appropriate commodity:

1. Two grades of beef meat
2. Milk
3. Pork
4. Poultry Meat
5. Eggs

These products are then processed, as appropriate, by the Processing Industry to determine food supply curves.

3.5.3 The Food Processing Industry Model (14)

In this model the crops and the livestock products destined for consumption are converted from wholesale goods to retail or consumer goods, and the appropriate costs of processing (margins) are computed. For example, the beef supply is converted from total animal weight into dressed meat weight, milk is divided into fresh milk and into other dairy products, while soybeans are crushed and then converted into soybean meal and oil. In the calculation of margins the average costs of energy, labor, storage, transportation, packaging, etc. associated with each retail commodity considered are taken into account.

3.5.4 The Food Supply Model (15)

The supply curve for each one of the following seventeen commodities is determined: (1) Beef, (2) Pork, (3) Poultry meat, (4) Eggs, (5) Milk, (6) Other Dairy Products, (7) Fish, (8) Wheat bread and flour, (9) Other Wheat Products, (10) Rice, (11) Soybean oil, (11´) Soybean meal, (12) Corn Products, (13) Sugar, (14) Potatoes, (15) Fresh Fruits and Vegetables, (16) Processed Fruits and Vegetables, (17) Cotton.

3.6 The Retail Food Market

3.6.1 The Consumer Demand Model (8)

This model includes the set of seventeen demand functions. The matrix of elasticities and cross-elasticities of demand has been rearranged so that it is in an irreducible form; this procedure facilitates the decomposition of the seventeen-dimensional problem into a sequence of interconnected lower dimensional ones (see also Section 3.4.1).

3.6.2 The Retail Food Market (16)

A supply-demand interaction is used to establish retail prices and consumption at the retail level. An iterative Regula Falsi algorithm is used to

determine the equilibrium solution.

3.7 The Consumption Analysis Sector (17)

The purpose of this sector is to generate a set of tables that display the average per capita consumption measured in calories per day and grams of protein per day. In addition, the data are disaggregated by income level using the information that is available for 1965. These tables are particularly helpful for analyzing in more detail the socio-economic impacts of alternative policies.

As indicated earlier, material flows and information flows link the above submodels into an integrated simulation model.

4. HISTORICAL SCENARIO

In order to test the integrated model and verify the various submodels, a case study based on past data has been carried out. The fifteen year period 1955-70 was used; the output of the simulation model was then compared to the data. The exogenous variables used to drive the model were taken from historical data; they are listed on Table 1.

TABLE 1

List of Exogenous Variables

- Population
- GNP
- Farm wage rate
- Industrial wage rate
- Interest rate
- Total domestic investment
- Government investment in agriculture
- Price support levels
- Support payments
- Acreage controls
- Government target price for sugar
- Commercial exports and imports
- Government exports (PL480)
- Time functions of technological change
- Prices series for gasoline, diesel fuel, natural gas, electricity
- Weather indices
- Population distribution by income groups

Government policies in effect during the period 1955-70 were modeled by introducing decision rules, wherever appropriate. Elaborate decision rules were not created to model government land policies, since such policies were not only complex and changing considerably from year to year, but also, in some sense, unique to that period. Rather, the effects of acreage allotments and controls were introduced into the model in the form of constraints on the amount of cropland available for individual crops. Results for wheat from one simulation in which the price trigger mechanism for grain reserves was tested are shown on Figures 4 to 7.

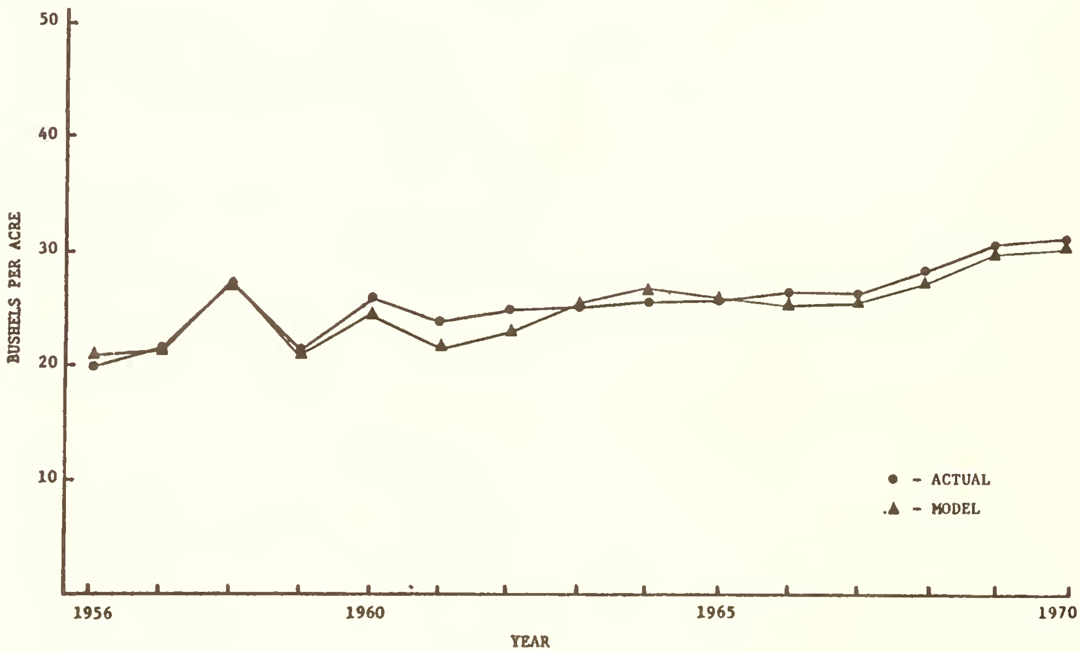

Fig. 4. WHEAT YIELD (BUSHELS PER ACRE)

5. CONCLUSIONS

The development of the basic version of AGRIMOD has been completed and model parameters have been estimated from published data. The code has been written in FORTRAN and has been implemented on a UNIVAC 1108. It has been estimated that approximately 45 secs are required to load the complete program and its data base. Computation time is approximately 12 to 15 secs. per simulated year; it is expected that reductions in running time will be achieved through improvements in the rate of convergence of the numerical optimization algorithms.

Current efforts are focused on the development of scenarios for carrying out policy analyses.

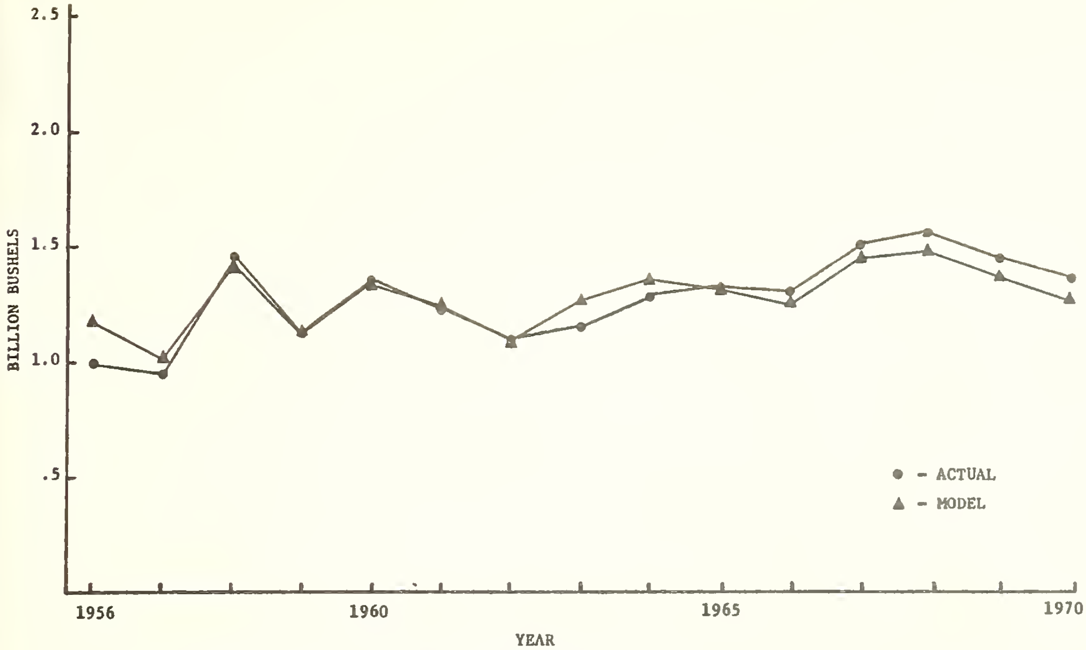

Fig. 5. WHEAT PRODUCTION
(BILLION BUSHELS)

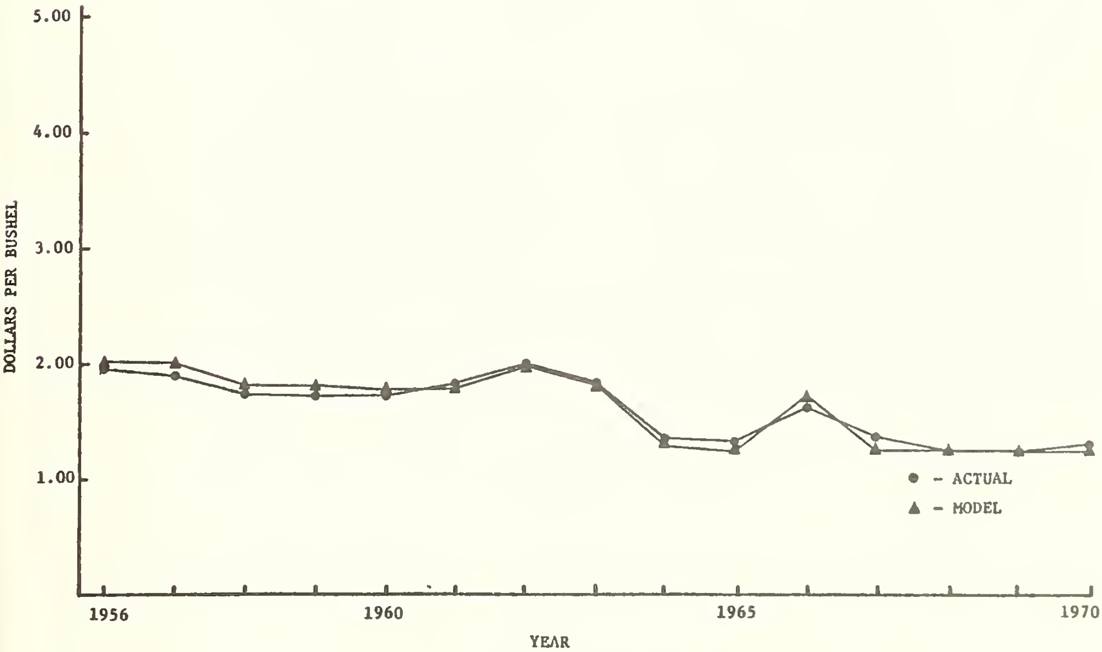

Fig. 6. WHEAT PRICE (FARM LEVEL)
(DOLLARS PER BUSHEL)

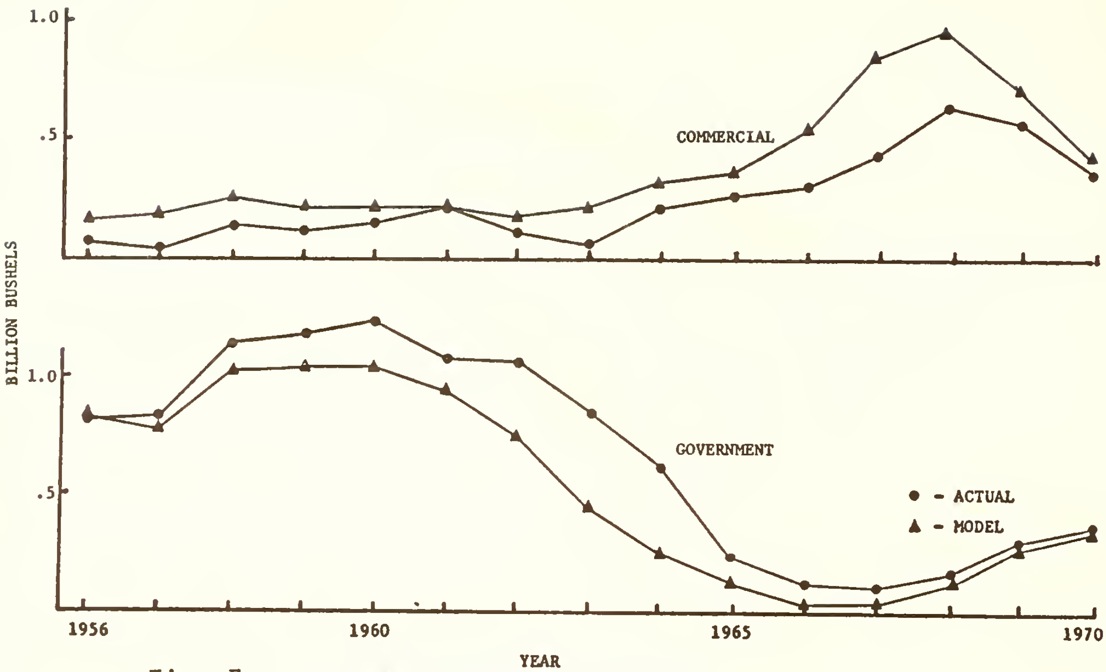

Fig. 7. WHEAT STOCKPILES - END OF SEASON (BILLION BUSHELS)

6. ACKNOWLEDGEMENT

The work presented in this paper is the result of team effort. During the last two years many staff members of Systems Control participated in the development of the model. Certain individuals, however, deserve special acknowledgement for their contributions as members of the project team: S. M. Haas, G. L. Campbell, D. N. Stengel, W. J. Winkler, and J. W. Cummins.

A project of such scope and magnitude cannot succeed without the aid of a substantial number of persons. The authors wish to acknowledge with appreciation the contributions of Professors D. G. Luenberger, G. L. Johnson, E. O. Heady, D. Kendrick, and Drs. L. Quance and W. Fishel of the U.S. Department of Agriculture; the assistance and guidance of Drs. A. Wade Blackman, A. Carl Leopold, and Richard C. Staples of NSF who acted as Program Managers; the constructive criticisms of the members of the Consulting Panel; and the staff of many agencies and departments of the federal government that provided data and much needed encouragement.

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GRAIN RESERVES FOR FEED GRAINS AND WHEAT IN THE WORLD GRAIN MARKET

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ABSTRACT

This paper analyzes how a United States grain reserve for wheat and feed grains can effect price variability for these commodities and how well wheat and feed grains substitute in a reserve. Reserve requirements are estimated for the commercial market. A comparison of the effectiveness of a price rule and quantity rule for operating a reserve is also provided, along with the cost estimates for the grain reserves.

INTRODUCTION

The grain reserve issue has been a major policy issue since world stock levels of grains were recently drawn down to historically low levels. Politicians, leaders of various farm and consumer groups, and others continue to debate the social desirability of a grain reserve. In this paper a model is discussed and some results are presented that should be useful in this continuing debate.

Previous studies of the buffer stock problem in an economic system have focused primarily on a single commodity. For example, Tweeten, Kalbfleisch and Lu (8)[1/] used a simulation model of the U.S. wheat economy to study the economic impact of a wheat reserve. Sharples, Walker and Slaughter (6) modified Tweeten's model and updated the results for wheat. Ray and Richardson (5) studied both wheat and feed grain reserve stocks, but the two were not related in an economic sense.

The objective of this paper is to use a model of the U.S. wheat, feed grains and livestock sectors to provide an economic analysis of establishing a buffer stock for wheat and feed grains. This analysis will consist of comparing (a) a situation in which the feed grain, wheat and livestock markets are allowed to operate freely with no government interference in the form of buffer stocks (a free market situation), with (b) a situation in which reserve stocks for both wheat and feed grains are established and are used to buffer some of the swings in the prices of these two commodities. The comparison consists of providing empirical estimates of prices, quantities consumed domestically and sold abroad, and government costs for operating the reserve stocks.

[1/] Underscored numbers in parentheses refer to references listed at the end of the report.

The question of a reserve stock arises in part due to the shocks of unforeseen events such as poor weather domestically, and sudden shifts in the foreign demand for our grains. The latter may be due to either poor weather or changes in the policy of foreign governments. These unforeseen events are captured in the economic model in the form of random variables. The effect of incorporating random variables in the analysis allows for reporting not only the mean values of the items mentioned above, but measures of dispersion as well.

In our analysis of reserve stocks of both wheat and feed grains, we wanted to include five interactions: (1) the covariance of wheat and feed grain yields in the United States, (2) the covariance of wheat and feed grain exports, (3) the livestock-feed interrelationship (i.e., stabilizing the feed price will have a direct impact on the livestock sector), (4) the use of wheat for feed by domestic livestock, and (5) the cross-price elasticities of supply of wheat and feed grain.

The next section of the paper contains an explanation of the equations which make up the models of the wheat, livestock, and feed grain sectors, including the linkages among sectors. An explanation is also included of how these models are then used to analyze the free market and reserve stock situation. The model description section is followed by a section which reports the results of the two situations (free market and reserve stocks). Under the reserve stocks situation two decision rules are applied. The first assumes acquisition and release (price rule) decisions are triggered by world price. The second assumes these decisions are made based on world production of wheat and feed grains (quantity rule). Then a final conclusion section summarizes the findings of this report.

THE WHEAT-FEED GRAIN SIMULATOR

The wheat-feed grain simulator is specifically designed to analyze government buffer stock management rules. It shows how alternative rules affect the level and variability of grain supply and demand, livestock, incomes of farmers, prices and government costs. Simulations focus on the distribution of possible future events rather than just examining the most likely events. It is the deviation from the most likely that generates the need for a buffer stock. Two major sources of annual variability in the U.S. wheat and feed grain markets are yields and export demand.

The simulator is an abstract of the U.W. wheat and feed grain markets specifically designed to analyze buffer stock programs.[2/] It contains short-run (annual) supply and demand functions for 1976 through 1982. The supply function incorporates a linear cobweb production response, i.e., production this year is a linear function of last year's average wheat and feed grain prices. The simulator in its present form contains linear demand functions.[3/]

2/ The model is conceptually similar to the one used by Tweeten, Kalbfleisch and Lu (8), and Sharples, Walker and Slaughter (6).

3/ Based upon our earlier work with the wheat simulator, we will eventually want to use constant price elasticity demand functions.

Both supply and demand functions contain random disturbance terms, giving a distribution of short-run supply and demand curves for each of the seven years, and, consequently, a distribution of annual equilibrium prices for each of the seven years.

The general operation of the simulator from year to year and from iteration to iteration is illustrated in figure 1. Starting with a selection of random numbers to use in the supply and demand equations in the first 7-year iteration, production, use, average annual market price, and other items for year 1 (1976) are computed. The market price, ending level of government buffer stocks, and livestock inventory at the end of year 1 are used to compute year 2 and so on, through year 7. Information from each year is stored for later analysis. The second iteration of the seven years begins with the same set of starting values but a new set of random numbers. The 7-year sequence is repeated 500 times. Results are then summarized for each year and for the 7-year period. Results reported herein are obtained from the summary of the 7-year period.

A flow chart of the simulator is shown in figure 2. After the selection of a large file of random numbers and after starting values are read, production is computed based on last year's wheat price and feed grain price. If a government stock program is in force, the stock management rule is used to determine appropriate government stock activity that year. If no stock program is in force this step is skipped. Production is then allocated to domestic use and exports, equilibrium grain prices are computed, and all results are stored to be printed out in a summary report. The simulator then cycles to the next year.

In the simulator there is a set of equations to describe the wheat, feed grains, and livestock sectors using a partial equilibrium approach. The submodels for each sector consist of equations for annual quantity supplied, quantity demanded, and price. The submodels are linked by endogenous variables common to all three sectors. The equations are given below by sector. The acres planted equations were estimated using the technique of seemingly unrelated regressions, and the demands for both feed grain and wheat along with the livestock sector were estimated using three-stage least squares. The detailed econometric results are not provided in this report but all coefficients conform to a priori expectations and most appear to be significantly different from zero as indicated by their size in relation to their respective standard errors.

The basic structural models employed by the authors were obtained from previous studies. These studies were modified only where deemed appropriate by the authors and were reestimated to bring them up to date. They were estimated simultaneously due to their linkage. The livestock and feed grain subsector model was taken from Feltner (2). The wheat demand model was taken originally from Barr (1). The crop supply equations were based upon results obtained from Walker and Penn (9), and Garst and Miller (3).

After obtaining the structural parameter estimates the restricted reduced form was calculated in order to historically validate the model. The restricted reduced form satisfied the criterion for dynamic stability according to the methodology provided by Theil and Boot (7).

FIGURE 1.

Illustration of the linkage between years and iterations in the wheat-feed grain simulator.

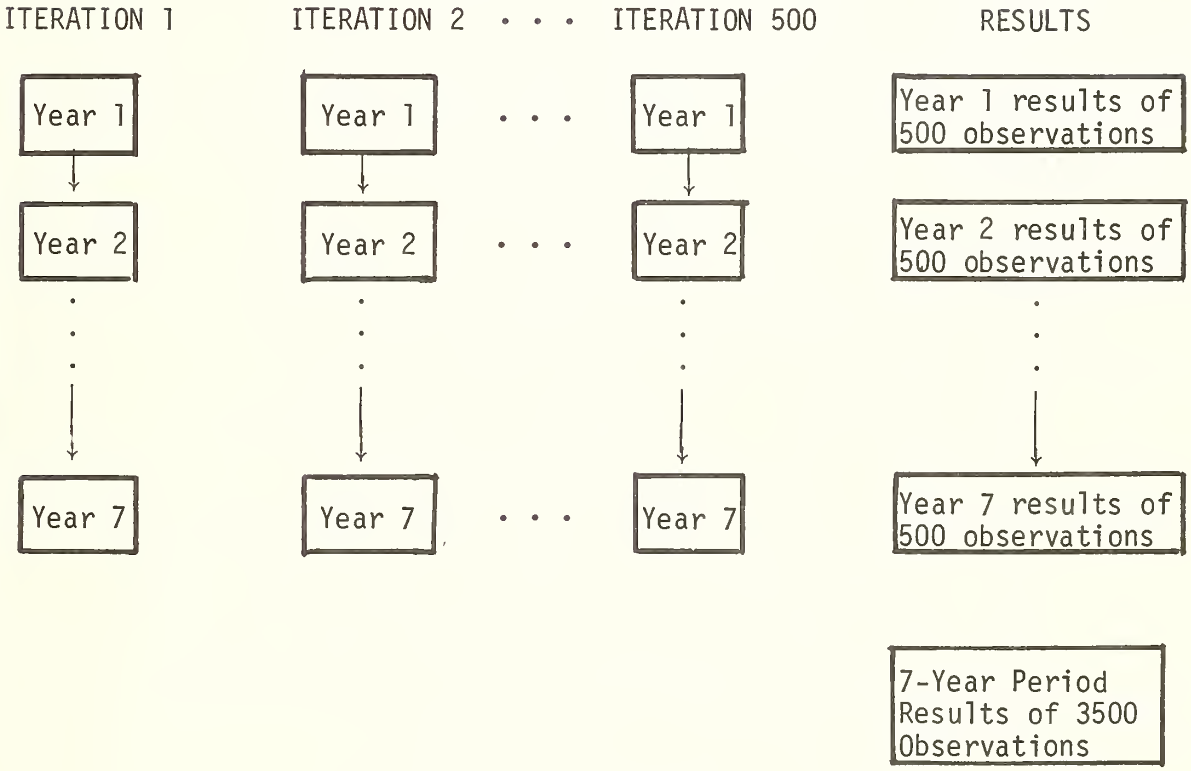
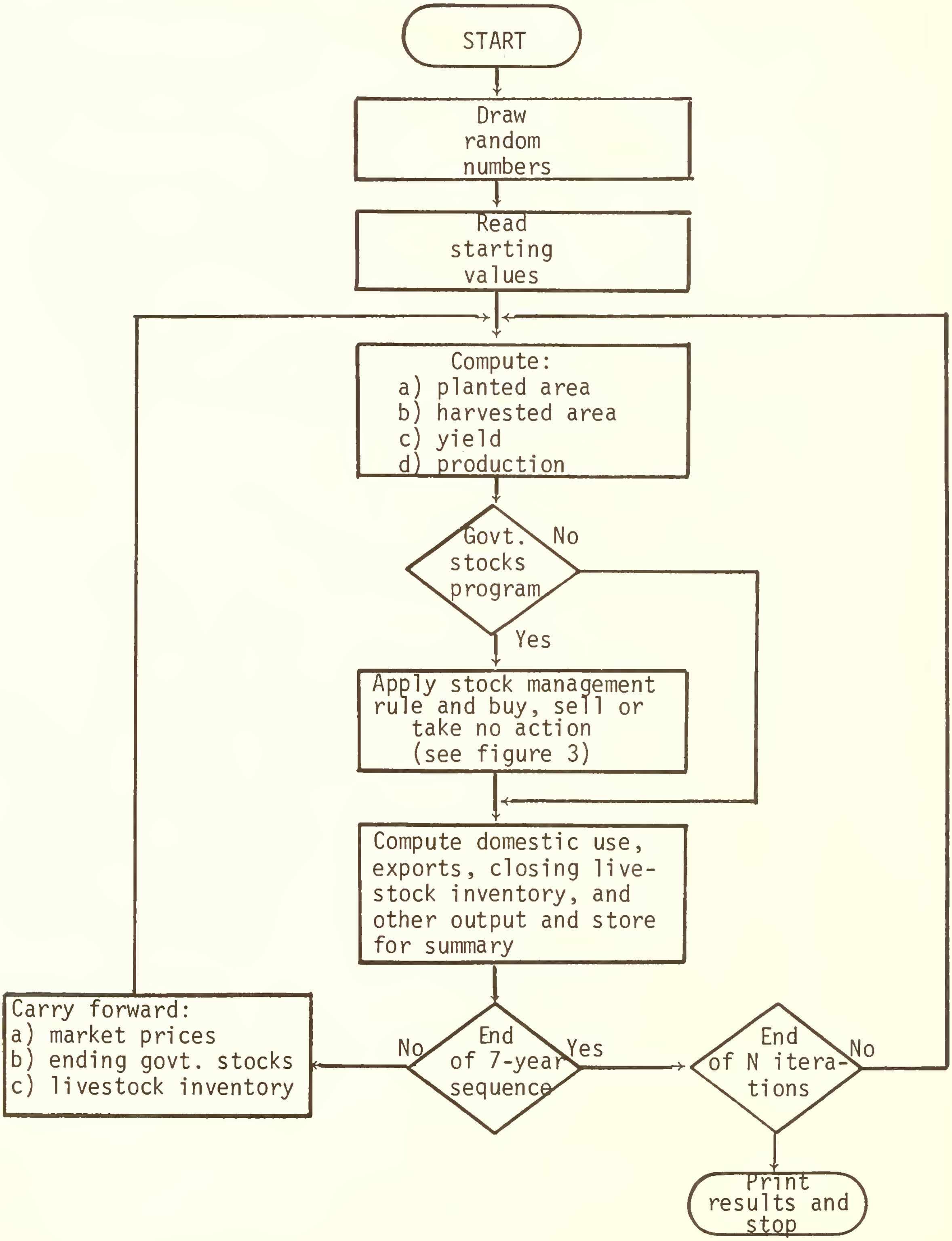


FIGURE 2.

Flow chart of wheat-feed grain simulation model.



THE WHEAT SUBSECTOR

Wheat Supply

(1) $AHW_t = 19{,}497 + 95.55PW_{t-1} - 45.5PF_{t-1}$

(2) $YW_t = 21.1 + .4t + \delta_{1t}$

(3) $QWS_t = AHW_t \times YW_t/10{,}000$

where:

AHW_t = area of wheat harvested (thousand hectares),

YW_t = yield of wheat (quintals per hectare),

PW_{t-1} = price of wheat in the previous year (\$ per metric ton),

PF_{t-1} = price of feed grains in the previous year (\$ per metric ton),

QWS_t = quantity of wheat produced (million metric tons),

δ_{1t} = random disturbance, distributed normally with mean zero, standard deviation of 1.34 quintals per hectare, and correlated .6 with δ_{2t},

t = time (1976 = 1, 1977 = 2, ...).

Wheat Demand

(4) $QWDOM_t = 80.0 - .109PW_t + .132PF_t - .001Y_t + 1.475t - .624GC_t - .03WPI_t$

(5) $QWEX = 51.0 - .183PW_t + .56t + \varepsilon_{1t}$

where:

$QWDOM_t$ = quantity of wheat demanded domestically (million metric tons),

Y_t = per capita disposable income (dollars),

GC_t = grain consuming animal units on farms, October 1 (beginning inventory of animal units for the current feed year),

WPI_t = wholesale price index for industrial commodities (1967 = 100),

$QWEX_t$ = quantity of wheat demanded for export (million metric tons),

ε_{1t} = random disturbance term, distributed normally with mean zero, standard deviation of 12 million metric tons, and correlated .5 with ε_{2t}.

THE FEED GRAIN SUBSECTOR[4/]

Feed Grain Supply

(6) $AHFG_t = 30{,}844 + 142.8PF_t - 29.4PW_t$

(7) $YFG_t = 46.18 + .67t + \delta_{2t}$

(8) $QSFG_t = AHFG_t \times YFG_t/10{,}000$

[4/] Feed grains are defined as oats, barley, corn, and sorghum.

where:

$AHFG_t$ = area harvested of feed grains (thousand hectares),

YFG_t = yield of feed grains (quintals per hectare),

$QSFG_t$ = quantity of feed grains produced (million metric tons),

δ_{2t} = random disturbance, normally distributed with mean zero, standard deviation of 3.36 quintals per hectare and correlated .6 with δ_{1t}.

Feed Grain Demand

$$(9)\ QFGDOM_t = 561.51 - 1.017PF_t + .25PW_t - 5.51GC_t + .023Y_t - .275WPI_t + 3.627_t + .054PP_t$$

$$(10)\ QFGEX_t = 31.1 - .31FP_t + .211PW_t + .988t + .1PP_t + \varepsilon_{2t}$$

where:

$QFGDOM_t$ = quantity of feed grain demanded domestically (million metric tons),

$QFGEX_t$ = quantity of feed grains demanded for export (million metric tons),

PP_t = index of the price of the eleven high protein feeds (1967 = 100),

ε_{2t} = random disturbance, normally distributed with mean zero, standard deviation of 15 million metric tons, and correlated .5 with ε_{1t}.

THE LIVESTOCK SUBSECTOR

$$(11)\quad PL_t = 2{,}137 + 1.021PF_t - 25.0GC_t + .087Y_t - 1.2WPI_t$$

$$(12)\quad QL_t = .496 + .00461Y_t - .0639WPI_t + .391t - .0522PF_t + 1.273GC_t$$

$$(13)\quad GC_{t+1} = 159.82 - .134PF_t - .99GC_t + .004Y_t - .047WPI_t + .527t$$

$$(14)^{5/}\quad GC_{t+1} \leq GC_t + 2.78$$

where:

PL_t = index of prices received by farmers for livestock and livestock products (1910-14 = 100),

QL_t = index of quantity of livestock and livestock products produced by farmers (1967 = 100),

GC_{t+1} = grain consuming animal units on October 1 at the end of the feeding year (carryout of livestock).

OPERATION OF THE SIMULATOR

As indicated by figure 2, the first iteration consists of solving the system of equations for 1976. These equations require values for per capita

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5/ The last inequality was added to the simulator to restrict the annual increase in livestock to the largest increase observed historically.

disposable income (Y), wholesale price index for industrial commodities (WPI), and the index of the price of the eleven high protein feeds for each year from 1976 to 1982. In addition, to start the first iteration, 1975 values are needed for the endogenous variables; price of feed grains (PF), price of wheat (PW), and the beginning inventory of grain consuming animal units on hand October 1, 1975. In addition, if the simulation is for the reserve stock situation, the beginning government inventories of wheat and feed grains are also needed.

After obtaining the starting values equations (1) and (2) are solved to determine the 1976 area of wheat and feed grains to be harvested. Then random numbers are drawn for determining the yield of wheat and feed grains, equations (2) and (7). These random numbers are drawn from a bivariate normal distribution with the means for wheat yield (δ_1) and feed grains yield (δ_2) both equal to zero, the standard deviation of wheat equal to 1.3 quintals per hectare (or 2 bushels per acre), the standard deviation of feed grains yield equal to 3.3 quintals per hectare (or 5 corn equivalent bushels per acre), and a correlation coefficient of 0.6. These parameters were obtained by using the residuals from the estimated yield equations (2) and (7). Time series data were used for the period 1961-1974 for estimation purposes.

Then numbers are drawn for the random variables ε_1 and ε_2 which appear in the export demand equations for wheat (equation 5), and feed grains (equation 10). These random numbers are drawn from a bivariate normal distribution with both means equal to zero, standard deviation for wheat exports equal to 12 million metric tons, standard deviation for feed grain exports equal to 15 million metric tons, and a correlation coefficient of .50. These parameters were obtained from the residual correlation matrix provided by the estimation procedure.

The quantities supplied of wheat and feed grains for 1976 are determined by solving equations (3) and (8) after determining the yields using equations (2) and (7). Then by setting quantity supplied equal to quantity demanded prices of wheat and feed grains can be obtained by solving equations (4) and (5) for the price of wheat and equations (9) and (10) for the price of feed grains. Quantities used domestically and exported can now be computed since prices are known. They are substituted in equation (4) and (5) to determine domestic and exported quantities for wheat. Similarly quantities of feed grains used domestically and exported can be obtained using equations (9) and (10).

Livestock price, quantities supplied, demanded and carryout of grain consuming animal units can now be computed by proper substitution of known values in equations (11), (12), and (13), respectively. We now have values for feed grain price, wheat price, and beginning inventory of grain consuming animal units, all that is needed in order to solve for the endogenous variables for the next year, 1977. This process is repeated until the end of the simulation period, 1982. Then a new iteration is begun with the original start values and a new set of random variables.

A FREE MARKET SIMULATION

The wheat-feed grain simulator is first run without a buffer stock program. The "No" branch from the "Government Stock Program" in figure 2 is taken.

The only linkage between one year and the next is the set of lagged prices in the supply equations (the 1975 prices per metric ton were wheat - $128.60, and feed grains - $103.60), and grain consuming animal units (set at 78 million). Results from the free market simulation are used (a) to make some qualitative judgements about the validity of the model, and (b) to serve as a base for evaluating results from the buffer stock simulation.

In order to provide some measure of model validity the simulation results for 1976 to 1982, assuming no government programs, are compared with recent historical data. Overall, the model appears to perform satisfactorily. The linkages among the feed grain, wheat and livestock sectors appear to be performing properly. Fine tuning is still needed, however. Mean values of key variables from the free market run for the 1976-1982 period are compared in table 1 with their historical levels over the 1972-1974 period. Production of both wheat and feed grains is higher than during the historical period--29 percent higher for wheat and 18 percent higher for feed grains. This is due to both higher yields and larger harvested area. Domestic use and exports expand as one would expect, but the expansion of domestic wheat use for feed is probably overestimated and the expansion of exports is probably underestimated. The model also shows an increase in the price of feed grains both in absolute terms and relative to the price of wheat. The simulator shows a 6 percent expansion of livestock with a 23 percent increase in prices relative to the historical period.

Measures of dispersion taken from the free market solution are compared with the 1960-1974 period. The historical period includes 12 years of stable prices and acreage controls, and the 3 recent years of large price changes and no controls. We expected that with no production or price control programs over the 1976-1982 period, variability of production and domestic use of grains would be about the same or lower than in the historical period, but variability of exports and price would be higher. Given these expectations, the coefficient of variation on wheat production and domestic use appear to be high, feed grain domestic use variability seems high, and feed grain price variability appears low. Livestock price variability also appears low.

A BUFFER STOCK SIMULATION

Given that the market conditions described by the free market simulation hold over the 7-year period, the next objective is to define and apply a buffer stock management rule to the simulator and observe its impact on the indicator variables (prices, quantities, government cost, size of stock).

The stock management rule is designed to reduce market price variability. The rule defines a stock purchase price and a stock sales price. When the market price drops below the purchase price, the stock manager buys that commodity at the purchase price until the market price equals the purchase price. When the market price exceeds the stock sale price, the stock manager sells that commodity at the sale price until either the market price is at equilibrium at the sale price or until the buffer stock is exhausted. If the market

TABLE 1
Mean values and coefficients of variation for wheat-feed grain simulation of 1976 to 1982, with historical comparisons.

Item	Unit[1/]	Historical data	Simulation results[2/]	
			Free market	Buffer stocks
		(1972-1974)		
Mean value of:				
Wheat harvested area	mil. ha.	22.5	26.1	25.9
Wheat production	mil. ton	45.8	59	59
Wheat domestic use	mil. ton	20.1	26	25
Wheat exports	mil. ton	30.6	33	34
Wheat price	dol./ton	119	110	110
Feed grain harvested area	mil. ha.	40.1	41.6	41.1
Feed grain production	mil. ton	172.5	203	201
Feed grain domestic use	mil. ton	145.5	156	153
Feed grain exports	mil. ton	37.4	47	48
Feed grain price	dol./ton	91	100	95
Livestock production	index	106	113	115
Livestock inventory	mil. GCAU	76	80	82
Livestock price index	index	440	539	501
Measure of dispersion of:	Coef. of	(1960-1974)		
Wheat harvested area	variation	.11	.16	.07
Wheat production	do.	.14	.17	.09
Wheat domestic use	do.	.12	.19	.12
Wheat exports	do.	.25	.24	.26
Wheat price	do.	.48	.53	.24
Wheat value of production	do.	--	.49	.24
Wheat value of exports	do.	--	.55	.44
Feed Grain harvested area	do.	.08	.08	.05
Feed grain production	do.	.14	.12	.09
Feed grain domestic use	do.	.10	.18	.11
Feed grain exports	do.	.38	.33	.30
Feed grain price	do.	.43	.37	.19
Feed grain value of production	do.	--	.34	.19
Feed grain value of exports	do.	--	.61	.44
Livestock production index	do.	.06	.04	.04
Livestock inventory	do.	.04	.04	.03
Livestock price index	do.	.25	.16	.10

1/ All units are metric (hectares and metric tons).

2/ Each item is calculated from 3500 observations (500 observations for each of 7 years).

price is between the purchase and sale prices, no stock management activity is called for.[6/]

The stock management rule is incorporated in the simulator as shown in figure 3.

The simple stock management price rule used here requires resolution of two issues. First, what should be the difference between the purchase price and the sale price? Our previous work with a wheat model (6) indicates that the smaller the difference, the greater the frequency of purchases and sales by the stock manager and the greater the constraint on the market price. A larger difference permits more market freedom but also less price stability. Second, at what level should the purchase and sale prices be defined? If set too high relative to the expected short-run equilibrium price, the buffer stock will tend to increase over time. On the other hand, if the prices are too low stocks will tend to be at low levels, increasing the probability of failure to achieve price stability objectives.

For the buffer stock simulation, the purchase price of wheat was $80 per metric ton, and the sale price was $140. The respective feed grain prices were $70 and $120. These prices were chosen somewhat arbitrarily. The price levels were set so that over the 7-year period stock purchases would equal stock sales and there would be no net change in the expected value of the buffer stock. The differential between the purchase price and the sale price was set such that the sale price was approximately 1.7 times greater than the purchase price. This differential allows a wide range over which the market price can vary, but allows the stock activity to cut off the peaks and valleys of the price distribution.

Simulation results suggest that with a buffer stock program the mean value of quantities produced and consumed change very little from the free market simulation, mean value of grain prices are about five percent lower, mean value of livestock prices are about seven percent lower, and price variability is reduced substantially (table 1). The buffer stock reduces the coefficient of variation on wheat and feed grain prices approximately 50 percent, and on livestock prices 38 percent. Figures 4 and 5 show the impact of the buffer stock on the distribution of wheat prices and feed grain prices.

There was also major reduction in variation of area harvested, quantity produced and quantity used domestically of both feed grains and wheat. Variation of quantity exported, however, was reduced only slightly for feed grains and actually increased for wheat. Having a buffer stock available allows quantity exported to fluctuate in response to changing foreign demand. Under the free market simulation, no stock was assumed to be available for use in years of unusually large export demand.

The buffer stock activity is summarized in table 2. Over the 500 iterations of the 7-year period, the wheat buffer stock averaged 18 million tons and the feed grain buffer stock averaged 23 million tons. The distribution of the 3500 observations on the combined wheat and feed grain buffer stock is shown in

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[6/] The size of the buffer stock is assumed to not affect the market price when the market price is between the stock purchase and sale prices. That implies that participants in the market have confidence that the stock management agency will follow the rules as specified in the simulation model. This is a controversial assumption. Some opponents of a publicly controlled buffer stock say that the mere existence of public stocks will depress prices.

FIGURE 3.

Flow chart of government decision rules for the bound price case.

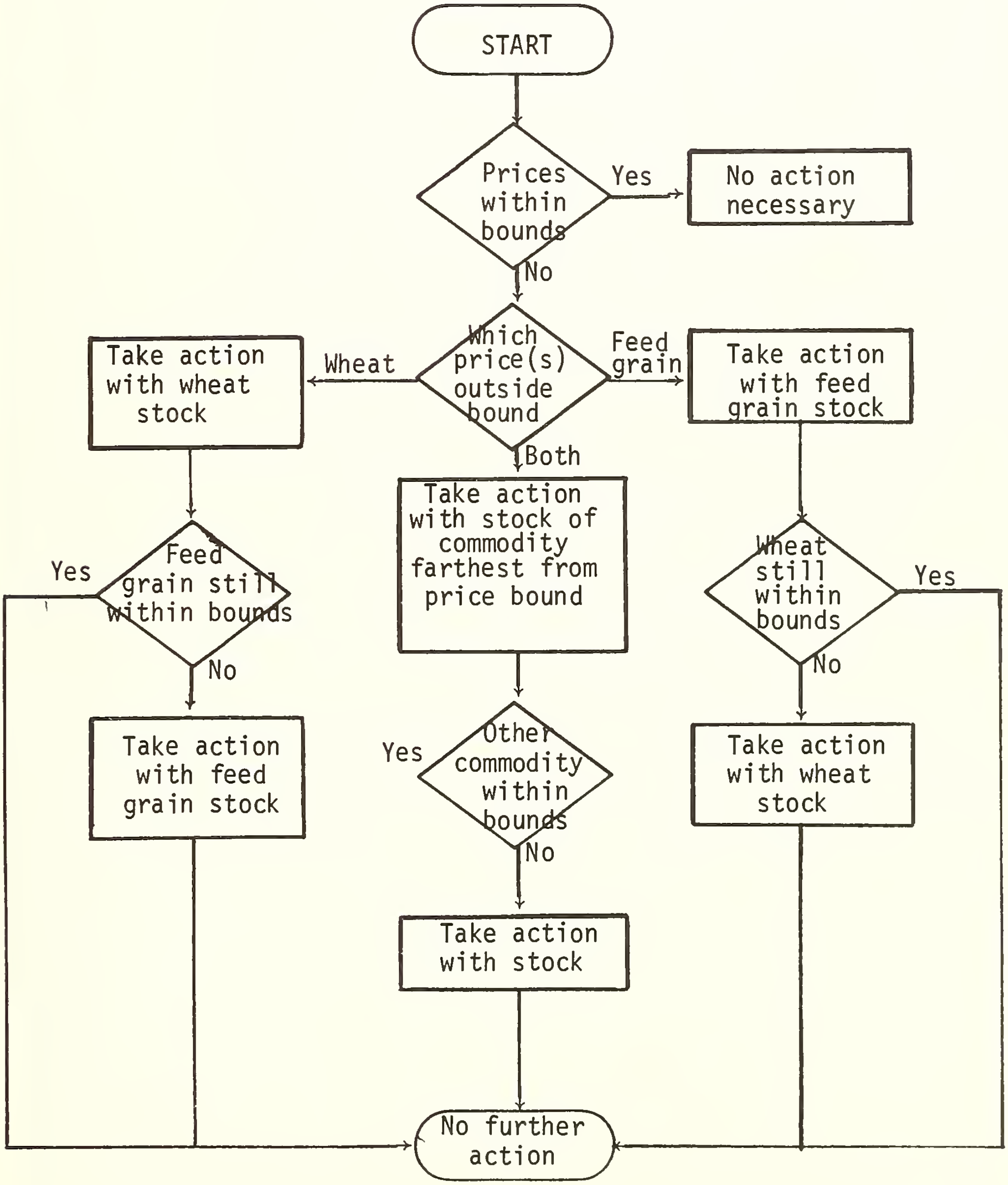


FIGURE 4.

Distribution of annual wheat price,
3500 observations, 1976-1982, free market and buffer stock solutions.

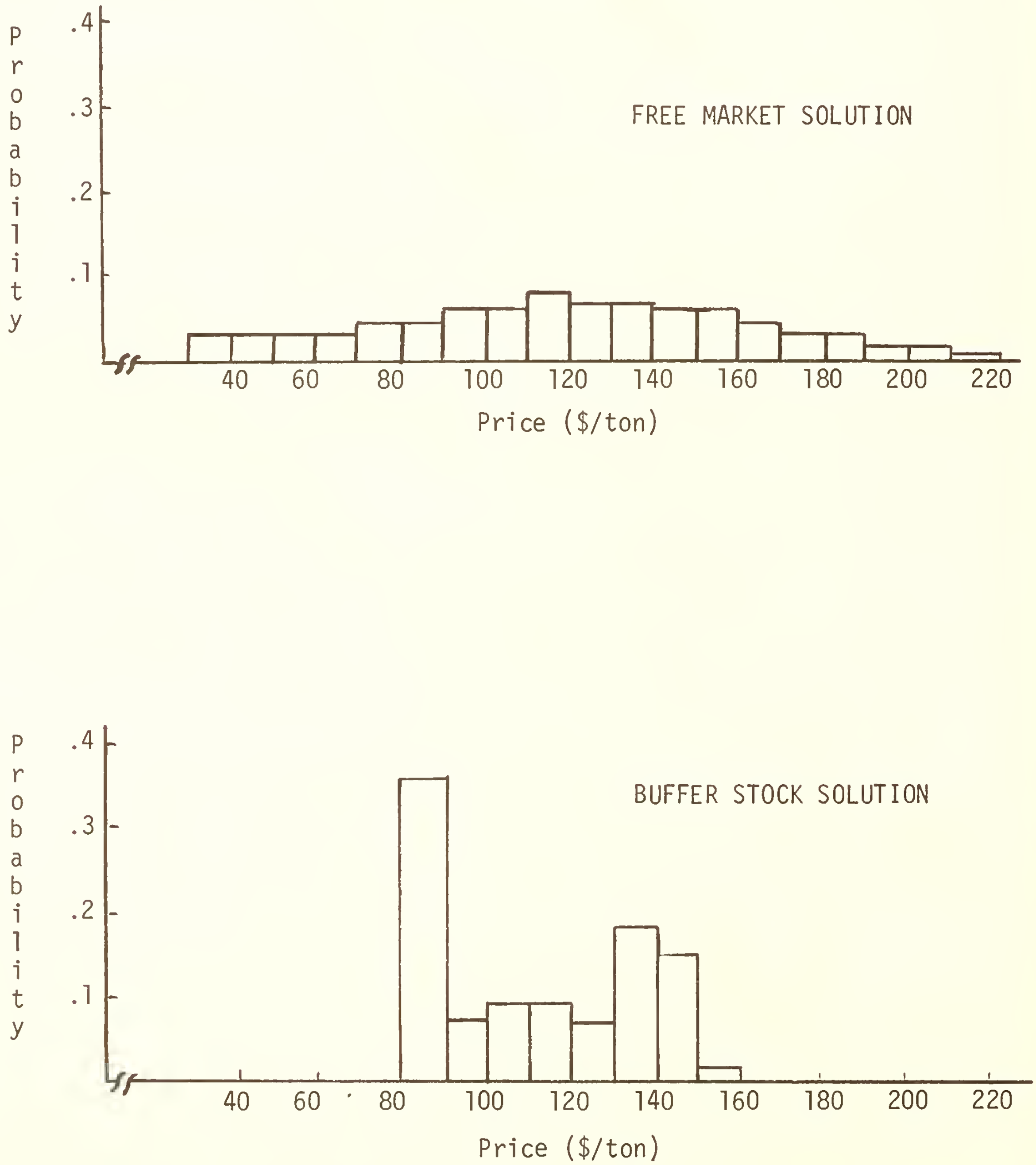


FIGURE 5.

Distribution of annual feed grain price,
3500 observations, 1976-1982, free market and buffer stock solutions.

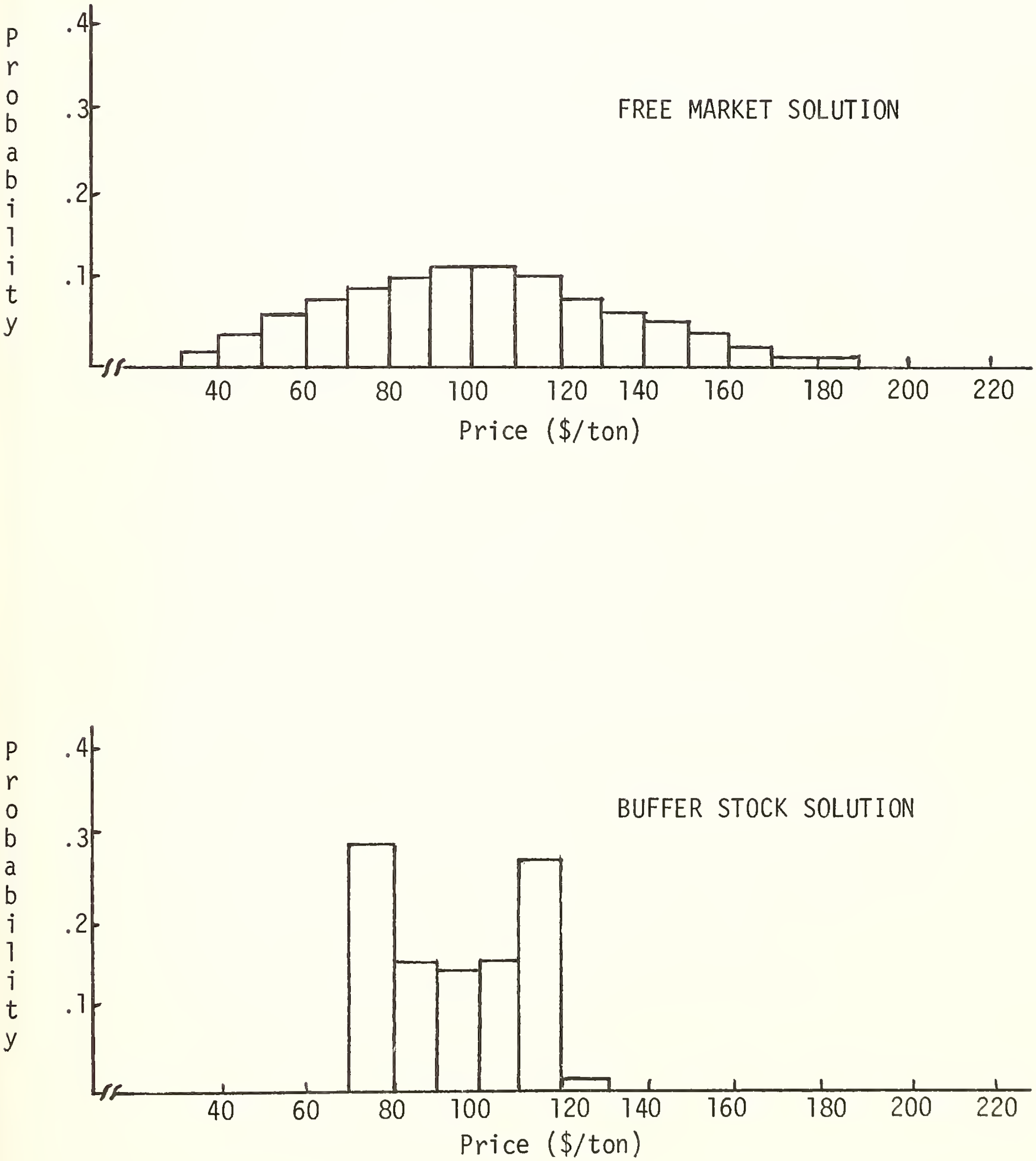


TABLE 2.

Mean values and frequencies for the government stocks management portion of the buffer stock simulation result, 1976-1982.[1]

Item	Wheat	Feed grains	Combined
	- - - -Million metric tons- - - -		
Mean value of:			
Buffer stock	18	23	41
	- - - - -Million dollars- - - - -		
Storage and interest cost[2]	248	293	541
Net storage cost[3]	165	224	389
	- - - - - - - -Percent- - - - - - -		
Frequency of:			
Stock purchase	29	14	--
Stock sale	27	14	--
No action	44	72	--
No stocks available	10	7	3
Stock below 10 million ton	26	16	8
Stock above 40 million ton	7	11	56
Government net storage cost being:			
Negative (profit made)	22	14	21
Over $1 billion	10	11	24
Over $2 billion	1	3	9

1/ Each item calculated from 3500 observations (500 observations for each of 7 years.

2/ Storage cost of $7.35 per ton and interest charge of 8 percent.

3/ Storage and interest costs plus value of purchases minus value of sales.

figure 6. Storage and interest costs for the combined average of 41 million tons of grain was $541 million. When the net profits from the purchase and sale of grain from the stock is subtracted from the storage and interest costs, the net cost of the buffer stock is reduced to $389 million. The distribution of the government net storage cost (figure 7) shows that in one-fifth of the years the storage activity generates a surplus because of relatively large sales, but in about 9 percent of the years the annual cost exceeds $2 billion, because of large quantities purchased.

In the simulator the wheat market demonstrates more price variability than the feed grain market. Consequently, when the buffer stock rules are applied, the simulation results show that stock purchases and sales are nearly twice as likely in the wheat market than in the feed grain market (table 2). Consequently, there is no government stock activity in only 44 percent of the annual observations in the wheat market, but there is no stock activity in 72 percent of the annual observations in the feed grain market. Also, note in table 2 that when the stock agency is depleted of wheat stocks, it tends not to be depleted of feed grain stocks.

The Quantity Rule

A buffer stock management rule based upon quantity, rather than price, has intuitive appeal. It is the variability in total quantity of food produced in the world from year to year that generates the need for stocks. Thus a management rule based upon variability in quantity produced would appear to attack the problem directly. A typical example of the quantity rule is in "The U.S. Proposal for an International Grain Reserves System", a Report to the September 29-30, 1975 Meeting of the International Wheat Council Preparatory Group (4). In the context of a world buffer stock, the rule is specified as:

$$\begin{array}{ll} \text{Purchase grain if} & AP > [(1.0 + K) \times TP] \\ \text{Sell grain if} & AP < [(1 - K) \times TP] \end{array} \qquad (15)$$

where:

AP = actual production,

TP = trend production,

K = a percentage deviation of actual production from trend production (usually 5 percent or less).

This quantity rule was examined in the simulator to observe its impact on U.S. markets. Results were compared with those from the price bounds rule. In the U.S. proposal, each major producing or consuming country would be responsible for a portion of the buffer stock. But in this analysis it was assumed that the United States would hold the whole buffer stock. This was done in order to have results comparable with those with a price rule where it was assumed the United States provided world price stability.

Several key assumptions were made in testing the quantity rule. The correlation between the random shocks on the U.S. export demand equations and the deviations of world production of wheat and feed grain from their trend levels was assumed to be -1.0. This assumption implies that when world production is above trend, U.S. exports are below their expected value. The converse is true when world production is below trend. This quantity rule would perform best (in terms of stabilizing the U.S. grain markets) compared with the price rule under this assumption. With lower correlation, this quantity rule might force the United States to purchase grain for the buffer stock when export demand was above its expected value and price was already high, or vice versa. Several

FIGURE 6.

Distribution of size of aggregate buffer stock, buffer stock solution with average level of 41 million tons, 3500 observations, 1976-1982.

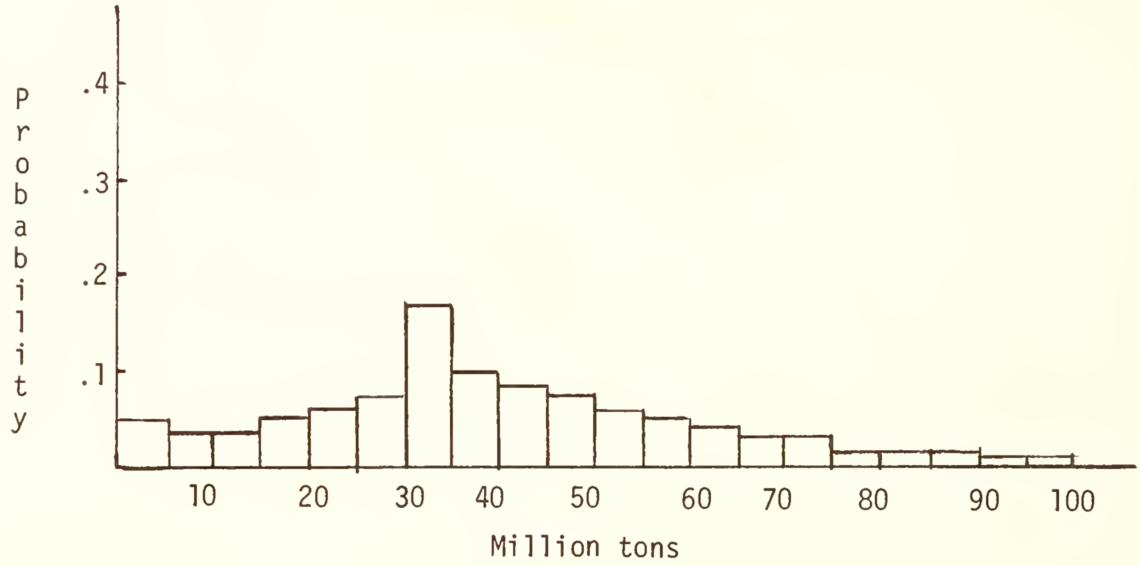
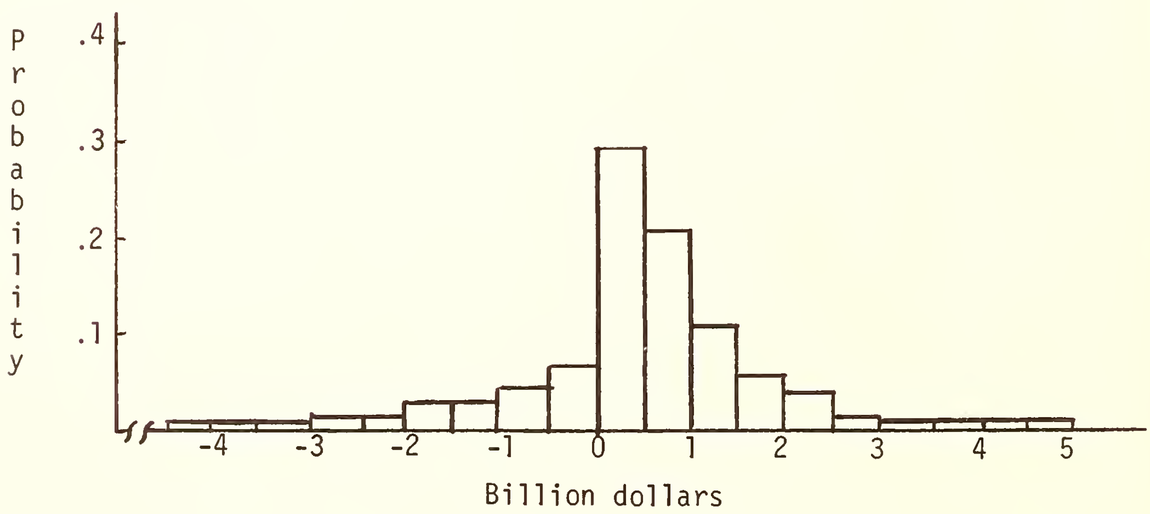


FIGURE 7.

Distribution of net U.S. Treasury outlay, buffer stock solution with average level of 41 million tons, 3500 observations, 1976-1982 (includes interest and storage cost plus sales minus purchases).



factors exist which would reduce this correlation. Countries which lack the effective demand to make up their shortfall would, in all likelihood, be included in world production. Factors which inhibit trade such as arbitrary policy decision regarding decisions to import would also lower this correlation.

In the simulation model, trend production was estimated for wheat and feed grains using time series data for the period 1960-1974.[7/] The estimated trend equations are:

$$WWP_t = 220.95 + 9.28t \qquad (16)$$

$$WFP_t = 371.61 + 14.31t \qquad (17)$$

where:

WWP_t = world production in million metric tons,

WFP_t = world feed grain production in million metric tons (corn, oats, barley, sorghum, and rye).

Equations (16) and (17) were used in the simulator to calculate trend production of the wheat and feed grains for the period 1976-1982. Actual world production of the commodities was calculated by adding a normally distributed random number to each equation. The parameters of the distribution for both commodities were obtained from the regression residuals. The means for both distributions are assumed to be zero, the standard deviations for actual world production from trend was estimated to be 14 million metric tons, and 18 million metric tons for wheat and feed grains, respectively.

Two simulations were made for the quantity rule. Purchases and sales were made if world production deviated two percent from trend and another was made allowing a five percent deviation in actual production from trend production before action was taken. Results from these rules are presented in tables 3 and 4. With the five percent rule, very few deviations from world trend production were greater than five percent. Consequently this results in very little stock activity as indicated by table 4. Purchases and sales were made 16 percent of the time for wheat, and only six percent of the time for feed grains under the five percent rule. However, with the two percent rule the stock agency is taking action over 50 percent of the time.

Applying the five percent rule results in little change in the variability of market variables (price and quantity) when compared with the free market. However, the two percent rule does invoke some stability the coefficients of variation of wheat and feed grain prices are reduced to .33 and .25, respectively. Although coefficients in the two percent rule do not stabilize the markets as much as the price rule previously discussed.

More stability could be obtained from the quantity rule by reducing the allowable percentage deviation from two percent to, say, one percent. However, it is possible that the correlation between the deviations in world trend production and exports may well be a more crucial parameter. Further simulations and sensitivity analyses on the correlation coefficients are needed before an opinion can be formed.

[7/] Sources: U.S. Dept. of Agric., Foreign Agr. Circ., FG12-73 October 1973, FG10-74 April 1974, FG23-74 November 1974, FG5-75 March 1975, FG6-75 April 1975; U.S. Dept. of Agric., World Agricultural Production and Trade, March 1973, June 1973, June 1974, September 1974; U.S. Dept. of Agric., Review of World Rice Markets and Major Suppliers, FAS M-246 August 1972; U.S. Dept. of Agric., Trends in World Grain Production: 1960 to 1972, FAS M-249 February 1973.

TABLE 3

Mean values and coefficients of variation for wheat-feed grain simulation of 1976 to 1982, using a quantity rule.

Item	Unit[1/]	Quantity rule results[2/,3/] Five percent quantity rule	Two percent quantity rule
Mean value of:			
Wheat harvested area............	mil. ha.	26	25
Wheat production................	mil. ton	59	59
Wheat domestic use..............	mil. ton	26	26
Wheat exports...................	mil. ton	33	33
Wheat price.....................	dol./ton	114	113
Feed grain harvested area.......	mil. ha.	41,537	41,339
Feed grain production...........	mil. ton	203	202
Feed grain domestic use.........	mil. ton	156	155
Feed grain exports..............	mil. ton	47	48
Feed grain price................	dol./ton	99	97
Livestock production............	index	113	115
Livestock inventory.............	mil. GCAU	80	81
Livestock price index...........	index	530	511
Measure of dispersion of:	Coef. of		
Wheat harvested area............	variation	.14	.10
Wheat production................	do.	.16	.11
Wheat domestic use..............	do.	.17	.14
Wheat exports...................	do.	.25	.29
Wheat price.....................	do.	.49	.33
Wheat value of production.......	do.	.45	.30
Wheat value of exports..........	do.	.53	.47
Feed grain harvested area.......	do.	.07	.06
Feed grain production...........	do.	.11	.10
Feed grain domestic use.........	do.	.17	.13
Feed grain exports..............	do.	.33	.32
Feed grain price................	do.	.34	.25
Feed grain value of production..	do.	.32	.23
Feed grain value of exports.....	do.	.58	.49
Livestock production index......	do.	.04	.04
Livestock inventory.............	do.	.04	.03
Livestock price index...........	do.	.15	.12

[1/] All units are metric (hectares and metric tons).

[2/] Each item is calculated from 3500 observations (500 observations for each of 7 years).

[3/] Quantity rules dictate purchases if world production is a specified percent above trend production and sales if world production is below trend production a specified percentage.

TABLE 4.

Mean values and frequencies for the government stocks management portion of the buffer stock simulation result, using a quantity[1/] rule, 1976-1982.[2/]

Item	Five percent quantity rule			Two percent quantity rule		
	Wheat	Feed grains	Combined	Wheat	Feed grains	Combined
	Million metric tons					
Mean value of:						
Buffer stock	16	20	36	18	22	40
	Million dollars					
Storage and interest cost[3/]	198	237	435	218	254	472
Net storage cost[4/]	133	216	349	167	233	400
	Percent					
Frequency of:						
Stock purchase	8	3	--	28	23	--
Stock sale	8	3	--	26	22	--
No action	84	94	--	46	55	--
No stocks available	3	1	--	12	11	--
Stock below 10 million ton	13	3	5/	33	23	11
Stock above 40 million ton	5/	2	20	9	14	42
Government net storage cost being:						
Negative (profit made)	8	3	7	25	18	27
Over $1 billion	1	5/	98	12	12	26
Over $2 billion	0	0	5/	4	4	10

1/ Quantity rules dictate purchases if world production is a specified percent above trend production and sales if world production is below trend production a specified percentage.

2/ Each item calculated from 3500 observations (500 observations for each of 7 years).

3/ Storage cost of $7.35 per ton and interest charge of 8 percent.

4/ Storage and interest costs plus value of purchases minus value of sales.

5/ Less than 0.5.

CONCLUSIONS

Preliminary results using the wheat-feed grain simulator show that a U.S.-owned buffer stock could greatly reduce U.S. (and world) grain price variability. It also has the side effect of reducing the variability of livestock prices. The cost, if run under the perfect knowledge conditions assumed in this analysis, could average under $400 million per year. The size of the stock and the annual cost to the government would fluctuate considerably, however, from year to year. In some years the stock would be depleted, while in other years the stock might exceed 80 million tons. Treasury costs in many years would be negative--i.e., profits would be made--because of large sales from stocks while in some years the costs could exceed $2 billion.

A quantity rule was tested assuming perfect correlation between the shocks affecting U.S. export demand and deviations in world production. The cost of the buffer stock program operated with a quantity rule is about the same as that incurred when operated with a price rule. The stabilizing effect of the quantity rule is less than that provided by the price rule.

Further work is needed to estimate association between deviations in world production from trend or expected level and U.S. exports. In addition, these estimates of this association or correlation need testing with regard to its effect on the results.

However, the econometric model used is only a preliminary attempt at describing the wheat, feed grain and livestock sectors. The aggregate nature of the livestock model may lead to considerable aggregation bias which could underestimate the stability invoked by the buffer stock program. The numerous criticisms of linear models are noted by the authors and are still valid. However, due to the complexities in modeling using nonlinear equations more time is needed in order to solve this problem. We obviously would prefer more valid functional forms from a theoretic viewpoint.

The assumption of constant private stocks is certainly open to question. Furthermore, we do not allow for changing variance of prices to effect the supply or demand relationships in the system. Neither do we analyze any of the potential effects of changing variability on capital investment in agriculture. The major contribution of this preliminary work is to incorporate the three sectors which are likely to be affected the most by buffering schemes into one model which recognizes the interrelationships between sectors. The model also allows for covariance between yields of feed grains and wheat as well as between the exports of the two commodities.

The model also allows results to be reported for the combined stock activity. The model does provide a rapid and efficient method for answering questions relating to buffer stocks providing estimates for government costs, gross income of producers, and the variability of key variables, such as price and quantities produced and consumed.[8/] In addition, a methodology was provided for analyzing buffer stocks in a multi-commodity system operated under both quantity and price rules.

[8/] One run with 3500 observations on the variables costs approximately $3.50 on a CDC6500 at Purdue University.

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FARM PROGRAMS AND GRAIN RESERVES -- SIMULATED RESULTS*

by

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ABSTRACT

A farm program with provisions for variable level nonrecourse loan rates and for set-aside is developed and evaluated. Loan rate levels and set-aside requirements are adjusted on the basis of expected commodity carryover levels in relation to prespecified target carryover levels. A stochastic version of the National Agricultural Policy Simulator (POLYSIM) was used to analyze price, carryover, farm income, government cost, and consumer food expenditure outcomes for a 1976-80 study period. A comparison of the target carryover program with 1973 Act provisions was made. The target carryover program showed less price and income variation, slightly higher net farm income, and a lower cost to the government in comparison to the Act of 1973 simulation.

INTRODUCTION

The turbulence in grain and livestock markets since 1972 has renewed interest in the establishment of grain reserves. Research interest has centered on questions of optimum grain reserve levels, incidence of costs and benefits of market stabilization, specification of rules for accumulation and release of reserves, and on who should hold ownership rights to reserves.

This paper focuses on development and analysis of a domestic commodity program designed to meet general farm policy needs and to provide grain

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*Opinions expressed in this article are those of the authors and do not necessarily represent the official views of the U. S. Dept. of Agriculture. Oklahoma State University Agricultural Experiment Station Professional paper P-280. This paper is based on a cooperative research project of the Oklahoma Agricultural Experiment Station and the Commodity Economics Division, Economic Research Service, U. S. Dept. of Agriculture.

reserves. International markets are recognized but the grain reserve is domestically held and regulated. The program presupposes that foreign buyers are aware of the general U. S. policy and that they deal in the export market accordingly.

The premises underlying the development of the general commodity program were that (1) maximum reliance be placed on the market place for channeling income to farmers and for allocation of production, (2) annual program provisions should be keyed to expected carryover levels because carryover from one marketing period to the next functions as a reserve, (3) ownership of carryover should be shared by farmers, the trade, and under certain circumstances, the government, and (4) because grain crops, especially feed grains, are demanded as livestock feed, reasonable grain price stability would be a program objective.

THE PROGRAM PROPOSAL

Loan Rates and Set-Aside

The proposed program will be keyed to the relationship between a target ending year carryover and the expected ending year carryover for feed grains, wheat, soybeans and cotton (rice, sugar, tobacco and ELS cotton are not included). Two key instruments will be nonrecourse loans and the use of set-aside acreage when needed. Nonrecourse loan rates will be varied depending on the relationship between target carryover and expected carryover levels, but the degree of loan rate variation will be limited by upper and lower loan rate bounds.

Figures 1 - 3 illustrate the program structure. Since program provisions are customarily announced prior to planting time, program administrators must deal with expected outcomes. The first step in determining provisions is the estimate of expected production based on expected price. The intersection of P*, the price expectation, with production schedule RR determines expected production, q_0 (Figure 1). A total supply quantity, q_1, is obtained by adding expected carryover from the marketing year in progress to expected production (Figure 1).

In Figure 2 the target carryover level is subtracted from available supply to determine desired utilization, q_u. Next the best estimate of the demand schedule, D_1D_1, is superimposed on the desired utilization schedule. The intersection of D_1D_1 with UU provides an estimate of a price that would result in a carryover level equal to the target carryover level if all expectations were realized. This price level becomes the announced loan rate, L_1 (Figure 3).

If demand was represented by D_2D_2 the intersection of D_2D_2 and UU occurs below the lower loan bound. For this situation the loan rate would be set at the lower loan bound, or L_2 (Figure 3). At this loan level expected carryover would exceed target carryover by an amount ab. In this case set-aside would be used to reduce production by an amount equal to ab eliminating the

Determine Expected Production (T)
And Expected Carryover (T-1)

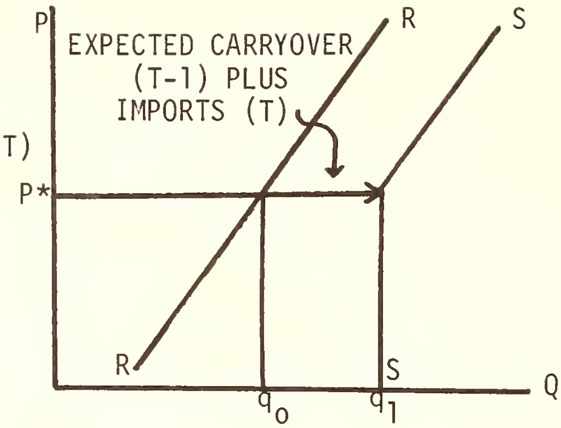

Figure 1

Determine Desired Utilization
To Meet Target Carryover

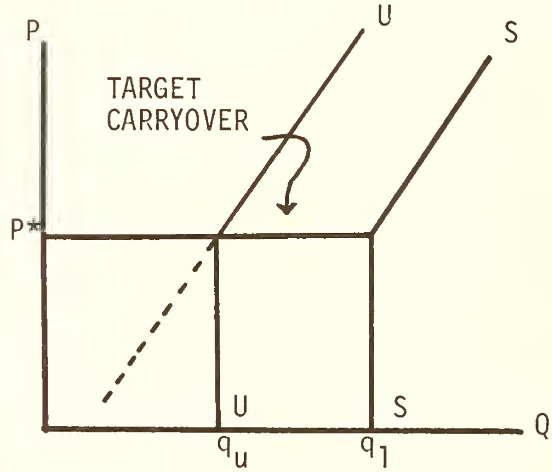

Figure 2

Determine Expected Demand
And Announce Loan Rate

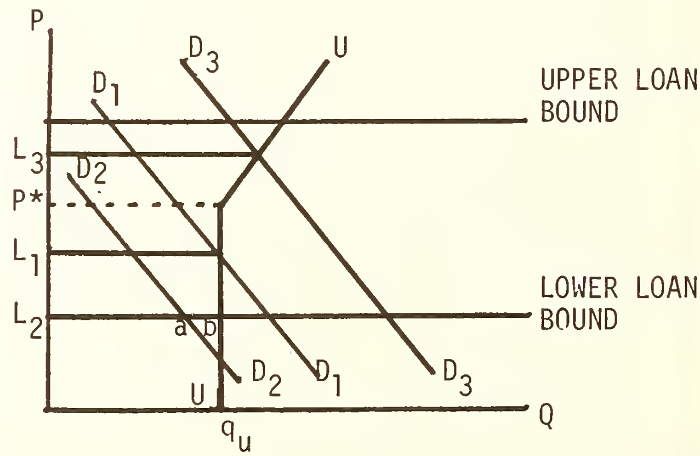

Figure 3

Illustration of Procedure for Determining Loan Rates

FIGURES 1 - 3

expectation of final carryover being above target carryover.

If demand was represented by D_3D_3 the intersection of D_3D_3 and UU would be above expected price P*, and the announced loan rate, L_3, would be above P*. Here the loan rate would have a positive influence on production and expected production would be greater than the q_o level shown in Figure 1.

A situation not illustrated is the situation where the intersection of demand with UU would be above the upper loan bound. In this case the loan rate would be set at the upper bound. No contingency provisions are specified in the program for this case so expected carryover would be less than target carryover at a market price equal to the loan rate with all other expectations fulfilled.

Setting the loan rate in the above manner does not guarantee that the carryover target will be met since the loan rate is set on the basis of expectations. Actual production and demand may be different than expected due to random and unanticipated events.

<u>Other Program Provisions</u>

The nonrecourse loans disbursed under the proposed program will carry a 30 month maturity. If the farmer has not repaid the loan plus interest after 30 months he can deliver the amount of commodity secured under loan to the Commodity Credit Corporation (CCC) as full payment in lieu of repaying principle and interest. The farmer is responsible for storage of the commodity while the loan is outstanding.

If set-aside is needed participating farmers will be paid a fixed per acre rate plus a variable payment made only if the average market price during the first half of the marketing year is above the loan rate. For the analysis reported here the fixed rate was $10 per acre and the variable rate was the difference between the market price and the loan rate multiplied by the normal yield on each set-aside acre. The variable rate assures participating farmers that they will not be made worse off than the non-participant if prices rise above the loan rate due to the effect of set-aside or unanticipated events.

The upper and lower loan bounds are important considerations for the proposed program. For this analysis of the proposed program the lower bound was equated to an estimate of direct costs of producing a unit of the commodity plus allocated overhead costs. The upper bound was equated to total unit costs of production which include land and management charges in addition to direct and overhead costs.[1] Cost of production estimates were based on data from the

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[1]Direct costs include costs of labor, power and machinery, seed, fertilizer and chemicals, custom services, irrigation, other materials, and operating capital. Overhead costs include an allocation of other costs such as personal property taxes, electricity, sales taxes, insurance, and farm auto costs. The management charge is based on a percent of gross -- continued on next page

1974 Cost of Production Survey (4).[2] The costs were updated to 1976 and then adjusted for the 1977-80 period on the basis of projections of the price index for production items, interest, taxes, and wage rates and on the basis of yield changes.

Stocks acquired by CCC through the nonrecourse loan program can be released whenever market prices are at least 115 percent of the upper loan limit.

Attributes of Proposed Program

Variable loan rates provide aggregate price feedback to individual farmers as a signal for desired aggregate production adjustment. The program offers price stability on the low side through the loan rate and has the objective of mitigating upward price swings by maintaining adequate carryovers through the target carryover concept. A high release price is specified for CCC stocks with the objective of having those stocks function as an emergency inventory. The high release price should also sooth farmer objections to government stocks.

Other things equal, the relationship between extending the loan maturity period and the level of CCC inventories should be inverse. With a longer maturity period fewer farmers will take loans because of the storage costs incurred to store the commodity until the loan matures. Also, farmers who do take out loans should have a better opportunity to advantegeously redeem loans prior to maturity under an extended maturity period.

The set-aside provision is provided as a means of preventing carryovers from becoming surplusses under conditions of slack demand or favorable weather and technological advances that lead to successive bumper crops.

The provisions can be adjusted to meet different objectives. Farm income can be supported by adjusting the lower loan bound. The degree of possible production incentive can be affected by adjusting the upper bound. Expected carryover levels can be affected by adjusting carryover targets. The loan maturity length will affect expected CCC inventories and the proportion of carryover held under loan. Price stability is affected by all of the provisions.

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1 - continued
farm sales allocated to crops according to their contribution to total value of production; (4, p. 2) explains the cost items in more detail. The basis for the loan limit values was Table 3 (4, p. 9). The current land value on a composite basis was selected to be representative of the land cost component.

[2] Underscored numbers in parentheses refer to references listed at the end of the report.

TABLE 1

Comparison of Program Provisions

Provision Category	Target Carryover Programs (1) 10-month loan maturity (2) 30-month loan maturity	Continuation of Act of 1973 Provisions
Carryover Level Targets	(1) and (2): Target ending year carryover levels are compared with expected carryover levels to set loan rates and to determine set-aside requirements. Targets: Feed Grains-45 million tons, Wheat-600 million bu., Soybeans-150 million bu., and Cotton 5 million bales	None
Non-Recourse Loan	(1) and (2): Loan rates vary between upper and lower bounds depending on relationship between target carryover and expected carryover. Lower limit-variable costs of production+machinery depreciation. Upper limit-total cost of production including land. Loan rate bounds: Adjusted annually to reflect expected changes in per unit costs of production. See Table 4.	Loan rates for feed grains, wheat and soybeans are constant over the 1976-80 period. Loan rates for cotton are adjusted each year. See Table 4.
Loan Maturity Length	(1): Matures at end of crop year, assumed average length of 10 months. (2): Matures 30 months from date of disbursement.	Mature 10 months after disbursement. Assumed to mature in crop year t+1.
Target Price and Deficiency Payments	None	Deficiency payments are in effect for feed grains, wheat and cotton. Payment based on difference between target price and market price. The loan rate is substituted for market price if market price is below the loan rate. Payment covers normal production on participants allotment. See Table 4.
Disaster Payments	(1) and (2): Included at a constant level as part of the $700 million minimum government payment level that also includes other support and conservation programs.	Included at a constant level as part of the $700 million minimum government payment level that also includes other support and conservation programs.
Set-aside Acreage	(1) and (2): Set-aside used for feed grains, wheat, soybeans and cotton whenever respective loan rate is at the lower bound. Set-aside is determined as the acreage to be idled to reduce expected carryover to the target carryover level.	None
Set-aside Payments	(1) and (2): A fixed payment of $10 per acre set-aside plus a variable payment calculated as the difference between market price and the loan rate (if market price is greater) times normal yield times set-aside acreage.	None
Release Price for Government Held (CCC) Stock Inventory	(1) and (2): 115 percent of the upper loan limit.	115 percent of the target price. A pseudo target price of $3.56 per bushel was used for soybeans.
Payment Limits	None	None

ANALYTIC PROCEDURES

Programs Analyzed

This section discusses procedures used to analyze the program proposal. Two programs in addition to the program outlined earlier were analyzed for comparison. A 30 month loan maturity period was selected as one of the provisions of the proposed program. An identical program with a 10 month loan maturity was also analyzed (Table 1). A third set of program provisions included in the analysis was based on continuation of Act of 1973 provisions (Table 1).

The Simulation Model

The three alternatives were analyzed with a stochastic version of the National Agricultural Policy Simulator (POLYSIM). This simulation system analyzed a span of five years, 1976-80, treating each year in sequence. The sequence links directly to 1975 which is used as the starting state for U. S. agriculture. The five year study period was replicated 300 times by randomly drawing correlated yields and correlated exports for feed grains, wheat, soybeans, and cotton for each year. Yields and exports were drawn independently. The variance -- convariance matrices (Table 2) used in the analysis were developed from detrended yield and export data from the 1960-74 period (1).

TABLE 2

Variance-Covariance Matrices
for Yields and Exports

Yields

	Feed Grains	Wheat	Soybean	Cotton
Feed Grains	.02863	.06833	.07919	-.30454
Wheat		1.47044	.4989	.35329
Soybeans			.87813	-2.27509
Cotton				102.56709

Exports

	Feed Grains	Wheat	Soybean	Cotton
Feed Grains	23.36555	529.66820	82.81646	2.10066
Wheat		21386.80900	578.9385	77.71089
Soybeans			1831.92581	11.61387
Cotton				.95386

POLYSIM requires that a baseline situation be provided for each year that is to be analyzed.[3] The baseline - a supply, utilization, price and income situation for four crops and seven livestock classes - is a normalized estimate of conditions that would prevail if yields and demand (especially export demand) were to follow expected trends. Factors that would shift supply and demand such as yield changes, export changes, and new or changed program provisions can be introduced through the POLYSIM system which readjusts any affected baseline value by calculating an appropriate deviation as a response to the supply or demand shifters. The calculated deviation procedure is dependent on elasticities that relate price and quantity variables. Identity relationships are also specified where appropriate in POLYSIM (2, 3).

POLYSIM calculates the immediate and lagged response to an introduced shock. Shocks can be introduced each year or in any year in the analysis span.

Simulation of the proposed program required the addition of two subroutines to the POLYSIM system. These subroutines were needed to calculate loan rates and to simulate the nonrecourse loan actions.

Loan Rate Subroutine

The loan rate subroutine (LOANRT) follows the concepts illustrated by Figures 1 - 3. Expected production for a crop is the product of the baseline yield and calculated harvested acres for the year being analyzed. The previous year's carryover and an import estimate are added to expected production to provide an estimate of total available supply. The target carryover value is subtracted from total supply giving an estimate of utilization that would result in an ending year carryover equal to target carryover. The loan rate is set equal to the price estimate calculated by equating desired utilization with a quantity dependent total demand function. However, if the calculated loan rate is outside the upper or lower bound the appropriate bound is used as the loan rate. If the loan rate is above the previous year's crop price the subroutine iterates to take account of production response from a higher expected price. Cross effects of the loan rate on other crops are also considered in the iteration loop.

Set-aside is calculated whenever the loan rate is set at its lower bound. A quantity of set-aside acreage sufficient to reduce production by an amount as illustrated in Figure 3 is calculated and subtracted from the final calculated harvested acreage. Set-aside was assumed 85 percent effective for the analysis so set-aside acreage is greater than crop acreage reduction.

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[3] The baseline for this analysis was provided through the efforts of commodity analysts in the Commodity Economics Division, ERS-USDA and also through efforts of analysts in the National Economics Analysis Division. The baseline used the best up-to-date information available but is not an official forecast or projection of the USDA.

Nonrecourse Loan Subroutine

POLYSIM calculates product price and consistent product demands based on calculated deviations from the baseline. Ending year carryover is then calculated by identity. At this point the price information is transferred to the nonrecourse loan subroutine (NRLOAN). NRLOAN keeps a record of CCC inventories and outstanding loans to farmers. Analysis of the 5 year span begins with no CCC inventories or outstanding loans in this analysis.

NRLOAN is designed to work through a series of sequential steps (Figure 4). The first step in NRLOAN is to calculate a downward price adjustment assuming that any outstanding loans held by farmers are redeemed (this adjustment is for convenience in programming the subroutine; the quantity actually redeemed is evaluated later). Price is reduced to increase quantity demanded by an amount equal to the outstanding loans.

In Figure 4a, P_l, reflects an adjusted price assuming the outstanding loans shown in Figure 4c are redeemed. P_h reflects another possible adjusted price. Either P_h or P_l could result depending on the price level transferred to NRLOAN from the main program.

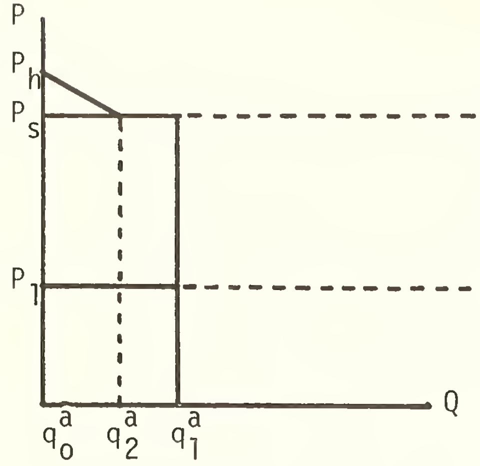
The next step in NRLOAN is to determine whether any of the inventory held by CCC would be released to the market. Figure 4a shows the quantity of CCC inventory, q_1^a and the release price P_s, with P_l less than P_s, CCC will not release any of its inventory to the market. At P_h CCC stocks are released until stocks are exhausted or until market price falls to P_s. In Figure 4a a quantity equal to q_0^a q_2^a would be sold on the market if the adjusted market price was P_h.

The next step is to determine the effect of the current loan rate on market price. An operating assumption for NRLOAN is that the CCC selling price for the current year is always greater than the current loan rate. The effect of the current loan rate on market price is based on the concept of a loan placement price. If market price is below the loan placement price, farmers will either keep nonmaturing outstanding loans, deliver mature loans to CCC, or take out new loans until the market price increases up to the loan placement price.

The loan placement price shown as P_L in Figure 4b represents the net value of a unit of product put under loan delivered to CCC. The net value is equal to the announced loan rate less the cost of storage over the length of the loan and less an in and out handling charge. In equation form the loan placement price is:

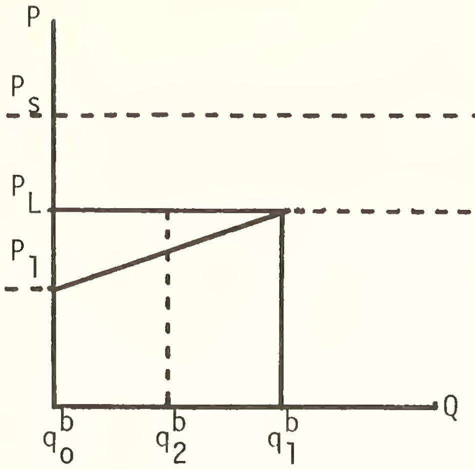
$$P_L = L - [(S \cdot M) + H] \qquad (1)$$

where P_L = loan placement price
L = announced loan rate



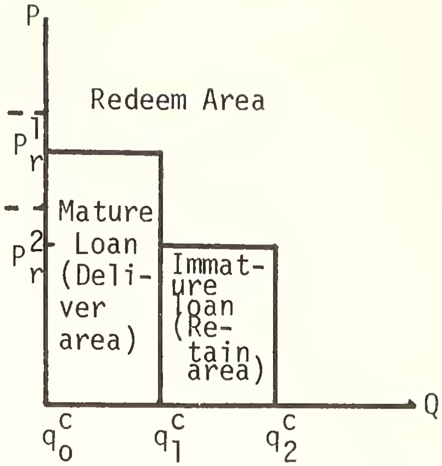
Adjust CCC Inventory

Figure 4a



Effect of Current Loan
Rate on Market Price

Figure 4b



Outstanding Loan
Adjustments

Figure 4c

Illustration of Nonrecourse Loan Subroutine (NRLOAN)

FIGURE 4

S = storage cost per month
M = months to loan maturity
H = in/out handling charge

If current market prices were below the loan placement price a producer could assure himself of a greater per unit net return by taking a loan and delivering to CCC when the loan is mature. Farmers holding loans are not prevented from taking advantage of favorable market prices anytime during the loan period.

Given an initial price of P_1, Figure 4b shows that the loan placement price which is based on the current loan rate would increase market price. A quantity of the commodity equal to $q_0^b\, q_1^b$ would have to be kept under loan, delivered to CCC, or taken out in new loans. The current loan rate, adjusted to reflect a loan placement price, would have no influence on market price if the adjusted market price was equal to P_s.

The next step in the subroutine is to reexamine the first assumption which was that all outstanding loans were redeemed. Figure 4c shows the amount of the commodity held under outstanding loans at the beginning of the year. Loans for different crop years are kept separate to allow for different maturity lengths and different redemption prices. A producer who has a mature loan has the option of delivering it to CCC or redeeming the loan. A producer who has an immature loan has the option of keeping the loan or redeeming the loan. The key variable for evaluating outstanding loans is the redemption price. The assumption, with respect to the redemption price, is that a producer will redeem a loan whenever the net per unit value on the market is greater than the net per unit value for delivering the loan to CCC. At any point in time the redemption price is equal to the loan placement price, which is the net value of a unit of production delivered to CCC, plus storage for the elapsed time plus the in/out handling charge plus the accumulated interest cost on the loan. In equation form the loan redemption price is:

$$P_r = P_L + H + (S \cdot T) + (L \cdot I \cdot T) \qquad (2)$$

where P_L, L, S, and H are defined as in (1) and
P_r = the loan redemption price
T = time in months since loan was disbursed
I = interest rate charged on loan if loan is redeemed

Figure 4c shows two outstanding loans, one mature and the other immature. The actions simulated by the subroutine will vary depending on the market price. A market price equal to P_s would be greater than the redemption price so both outstanding loans would be redeemed as initially assumed. A price equal to P_L would be below the redemption price of the mature loan so instead of being redeemed the mature loan would be delivered to CCC. The amount of the mature loan would be held off the market instead of being redeemed as originally assumed so the market effect would be the same as taking out a new loan. The effect is illustrated on Figure 4b by showing that $q_0^b\, q_2^b$ of the loan demand

$q_0^b\ q_1^b$ is met by the CCC delivery. If q_2^b were to the right of q_1^b, the action of delivering a mature loan to CCC would increase the market price. If not, the effect would be to reduce the amount of new loans to be taken out as is the case in Figure 4b.

Price P_L is above the redemption price of the immature loan in Figure 4c so this loan is redeemed as assumed and there is no further price effect. Farmers redeeming the immature loan realize a net gain compared to delivering the loan to CCC when it is mature.

The final market price in the Figure 4 example would either be P_s or P_L depending on whether the adjusted market price were P_h or P_l respectively. If the starting market price was P_l new loans equal in amount to $q_2^b\ q_1^b$ (Figure 4b) would be taken out. All loans outstanding at the start of the year would have been terminated by delivery to CCC or by redemption.

NRLOAN returns the final price to the main POLYSIM program and demand is recalculated if the commodity price has changed because of nonrecourse loan actions. The final total carryover level reflects inventories held by CCC, private stock held under loan, and private stocks held uncommitted.

NRLOAN also calculates costs associated with loan actions and any profits or losses associated with inventory adjustments. Farmers may be able to redeem loans at a price higher than the net delivered value. In this case the profits are added to net income. Their storage costs are deducted from net income.

CCC costs include storage and interest on the inventory, interest on the amount of loans disbursed, and any losses incurred on inventory transactions. Offsetting these costs are payment of interest on redeemed loans and any profit on inventory release. NRLOAN maintains an average per unit inventory value. The selling price of any inventory release is compared with the average per unit value to determine profits or losses.

RESULTS

Results of the stochastic simulations for the three program alternatives are presented in Table 3. The table shows the mean value, the coefficient of variation, the minimum value and the maximum value for selected variables that occurred for the 1500 annual situations simulated (5 years replicated 300 times). The table also shows the average value of the selected variables for each year which is an average over 300 annual situations.

Comparison of 30-month vs. 10-month Loan Maturity

The only difference between the two target carryover programs simulated was the loan maturity length. Differences in results can be attributed to that difference since the random selection of yields and exports followed the same sequence for both programs (and the Act of 1973 program as well).

TABLE 3

Summary of Results for Alternative Program Analyses

Item	Unit	Program	Five Year Span: Mean	Coefficient of Variation	Minimum	Maximum	Average Value by Year: 1976	1977	1978	1979	1980
Commodity Prices											
Corn	$ bu.	30-month	2.08	19.18	.93	3.75	2.23	2.01	1.90	2.00	2.28
		10-month	2.25	17.66	1.18	3.75	2.41	2.18	2.06	2.17	2.44
		1973 Act	1.99	22.63	1.01	3.87	2.10	1.94	1.84	1.92	2.20
Wheat	do.	30-month	2.76	17.39	1.56	4.63	3.32	2.91	2.59	2.47	2.54
		10-month	2.82	16.63	1.55	4.63	3.42	2.98	2.63	2.52	2.58
		1973 Act	2 69	19.17	1.28	4.63	3.23	2.90	2.59	2.39	2.38
Soybeans	do.	30-month	4.93	8.97	3.72	6.93	4.65	4.82	4.93	4.99	5.30
		10-month	5.03	9.06	3.86	7.19	4.65	4.91	5.03	5.12	5.46
		1973 Act	4.82	10.59	3.36	7.24	4.63	4.71	4.78	4.84	5.16
Cotton	$ lb.	30-month	.58	14.31	.38	.91	.55	.59	.56	.60	.60
		10-month	.59	12.69	.41	.92	.55	.59	.58	.61	.61
		1973 Act	.57	16.13	.34	.89	.54	.59	.56	.60	.58
Cattle and Calves	$ cwt	30-month	46.83	10.76	39.50	61.48	39.50	45.04	48.20	49.94	51.50
		10-month	47.85	11.34	39.50	61.99	39.50	46.36	49.37	51.20	52.80
		1973 Act	46.33	11.22	35.55	63.53	39.50	43.99	47.94	49.43	50.81
Total Net Farm Income	b.$	30-month	26.6	13.45	15.7	39.2	23.3	27.5	26.2	27.4	28.3
		10-month	27.9	14.12	16.4	39.4	23.1	29.6	27.7	28.9	30.0
		1973 Act	26.4	14.89	14.9	39.9	23.6	26.3	26.5	27.6	28.1
Total Government Payments	m. $	30-month	782.4	35.78	700.0	4028.6	700.0	852.4	789.0	796.9	774.0
		10-month	935.4	65.20	700.0	6798.4	700.0	1169.3	941.1	949.3	917.2
		1973 Act	1130.6	68.90	700.0	5183.8	857.2	1010.6	1221.8	1349.6	1213.9
CCC Operations Cost	do.	30-month	-26.9	-125.67	-212.0	145.7	-8.2	-18.8	-23.5	-35.0	-48.9
		10-month	-89.3	-73.85	-298.5	218.2	-34.0	-77.5	-95.6	-110.3	-129.2
		1973 Act	.0	-	-54.0	103.3	0.0	0.0	0.0	0.0	0.0
Consumer's Food Expenditure	b. $	30-month	201.8	10.41	172.1	242.0	172.1	188.0	201.6	215.9	231.3
		10-month	203.1	10.56	172.1	242.6	172.1	189.7	203.0	217.5	233.0
		1973 Act	201.0	10.42	172.1	243.7	172.1	186.5	201.1	215.1	230.3
Export Levels											
Feed grains	m.t.	30-month	53.2	15.40	27.36	85.5	47.7	49.4	53.2	56.3	59.3
		10-month	50.2	15.97	24.18	86.0	45.7	46.5	50.0	52.8	55.9
		1973 Act	54.7	15.88	27.26	89.7	49.2	50.7	54.5	58.1	61.1
Wheat	m.bu.	30-month	1223.8	7.96	814.3	1498.0	1184.3	1209.3	1236.8	1251.8	1236.5
		10-month	1205.3	8.45	781.8	1476.6	1168.1	1188.8	1218.6	1232.0	1219.2
		1973 Act	1241.6	7.90	837.4	1539.0	1197.4	1214.9	1238.0	1272.1	1285.7
Soybeans	do.	30-month	560.0	8.43	403.2	742.2	525.3	542.0	556.2	577.9	598.4
		10-month	550.7	8.07	403.2	730.3	525.3	535.3	545.7	564.3	582.9
		1973 Act	571.1	9.20	404.2	767.2	526.6	551.2	570.5	593.8	613.5
Cotton	m. bale	30-month	4.28	17.75	1.52	6.30	4.07	4.66	4.03	4.35	4.34
		10-month	4.24	18.24	1.47	6.24	4.06	4.63	3.97	4.29	4.26
		1973 Act	4.30	16.75	1.63	6.29	4.08	4.64	4.04	4.35	4.40

TABLE 3 - Continued
Summary of Results for Alternative Program Analyses

Item	Unit	Program	Five Year Span: Mean	Five Year Span: Coefficient of Variation	Five Year Span: Minimum	Five Year Span: Maximum	Average Value by Year: 1976	1977	1978	1979	1980
Ending Year Carryovers											
Feed grains	m.t.	30-month	40.5	36.12	9.0	90.3	36.8	42.6	44.1	40.5	38.3
		10-month	44.5	33.75	9.0	92.1	39.0	46.1	48.0	45.3	43.9
		1973 Act	39.3	35.71	9.0	85.4	34.7	40.2	43.5	41.0	36.8
Wheat	m.bu.	30-month	653.7	22.81	308.1	1094.2	438.6	606.9	707.0	749.2	766.7
		10-month	686.0	23.85	308.1	1092.6	455.7	644.1	751.0	787.0	792.2
		1973 Act	656.8	24.16	308.3	1214.6	425.4	590.2	706.6	771.3	790.6
Soybeans	do.	30-month	186.4	40.13	30.0	339.9	293.7	230.5	175.9	123.5	108.4
		10-month	198.1	33.44	35.2	339.9	293.7	228.5	181.9	143.5	143.0
		1973 Act	176.7	47.59	30.0	341.0	294.6	233.1	172.5	107.0	76.5
Cotton	m.bale	30-month	3.84	20.87	2.00	7.50	3.97	3.56	4.15	3.64	3.88
		10-month	3.92	21.77	2.16	7.58	3.99	3.58	4.20	3.75	4.09
		1973 Act	3.81	18.09	2.22	7.35	3.96	3.51	4.11	3.58	3.87
Set-Aside											
Feed grains	m.ac.	30-month	1.4	303.65	0.0	38.2	0.0	2.7	1.8	1.6	0.8
		10-month	2.8	231.42	0.0	47.7	0.0	6.1	3.4	2.8	1.7
Wheat	do.	30-month	.4	319.57	0.0	11.4	0.0	0.1	0.2	0.7	1.0
		10-month	.8	233.28	0.0	13.0	0.0	0.2	0.8	1.5	1.7
Soybeans	do.	30-month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		10-month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton	do.	30-month	0.00	1379.27	0.00	1.29	0.00	0.00	0.00	0.01	0.01
		10-month	0.01	1065.18	0.00	1.97	0.00	0.00	0.01	0.01	0.03
Loans Outstanding Year End											
Feed grains	m.t.	30-month	2.1	141.33	0.0	18.7	1.8	2.5	3.1	1.7	1.6
		1973 Act	0.0	1127.71	0.0	6.1	0.0	0.0	0.0	0.0	0.0
Wheat	m.bu.	30-month	12.5	247.08	0.0	170.7	15.4	21.2	20.6	5.1	0.0
		1973 Act	0.0	3872.98	0.0	3.8	0.0	0.0	0.0	0.0	0.0
Soybeans	do.	30-month	6.9	299.34	0.0	161.5	0.0	0.0	0.9	8.1	25.5
		1973 Act	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton	m.bale	30-month	0.06	248.92	0.0	1.24	0.02	0.02	0.06	0.08	0.13
		1973 Act	0.00	1147.86	0.0	0.53	0.00	0.00	0.00	0.00	0.00
CCC Inventory											
Feed grains	m.t.	30-month	0.8	251.16	0.0	17.1	0.0	0.0	0.0	1.8	2.3
		10-month	6.1	70.77	0.0	21.3	4.1	5.3	6.2	6.9	7.8
		1973 Act	0.0	1718.04	0.0	6.9	0.0	0.0	0.0	0.1	0.0
Wheat	m. bu.	30-month	7.2	338.09	0.0	170.7	0.0	0.0	0.0	15.4	20.5
		10-month	46.0	120.48	0.0	224.5	35.0	48.1	48.9	49.0	49.0
		1973 Act	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Soybeans	do.	30-month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		10-month	13.1	216.25	0.0	182.7	0.0	0.2	3.3	18.9	42.9
		1973 Act	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton	m.bales	30-month	0.00	869.68	0.00	.49	0.00	0.00	0.00	0.01	0.01
		10-month	0.12	177.59	0.00	1.32	0.04	0.05	0.12	0.16	0.25
		1973 Act	0.00	1929.91	0.00	0.72	0.00	0.00	0.00	0.00	0.00

No outstanding loans are carried over from one year to the next under the 10-month loan maturity. If NRLOAN calculated a loan demand, the loan quantities are held by farmers for 10 months and then delivered to CCC.

CCC held inventories are released if market price is at least 115 percent of the upper loan limit. An expected result would be a higher maximum price for a commodity when there are no outstanding loans to redeem because the market price would have to be above the release price before reserve quantities would be released by CCC. Soybeans and wheat did have higher maximum prices under the 10-month maturity but not substantially higher (Table 3).

With a 10-month maturity farmers would accrue a smaller storage cost between loan disbursement and maturity compared to the extended loan maturity alternative. This results in a higher loan placement price which would tend to result in a higher minimum price. Except for wheat, this was the case (Table 3). The higher minimums and maximums under the 10-month program contributed to a higher average price level compared to the 30-month alternative.

Another difference observed in the comparison was the higher average net farm income and higher consumer costs under the 10-month program. This was a result of slightly higher livestock prices due to higher grain prices. Exports were slightly less with the 10-month loan due to higher prices. The random export draws do not fix export levels at exactly the level drawn, rather the random draw replaces the original base export for that year and final export levels are calculated as deviations away from the adjusted base.

Production levels were lower even though prices were higher for the 10-month program. The higher prices reduced quantity demanded and this was reflected in a slight increase in set-aside acreage as the system adjusted to maintain target carryovers. Both average set-aside and average carryovers were higher under the 10-month maturity program. As an example, average acreage of feed grain set-aside under the 10-month program was 2.8 million acres, compared to 1.4 million acres under the 30-month program (Table 3).

CCC inventories in 1980 were two to three times larger under the 10-month program. With the 30-month program, CCC did not acquire any inventory until 1979 since that was the first year that loans, taken out in 1976, matured. There were no existing inventories at the start of 1976.

Average annual set-aside payments for the 10-month program were $152.9 million dollars higher than for the 30-month program. CCC operating costs were $62.4 million higher for the 10-month program so total government cost averaged $215 million more per year under the 10-month program. Average annual income was $1,315 million higher per year for the 10-month program in comparison to the 30-month program due to higher prices and larger government payments (Table 3). Consumer costs were also slightly higher under the 10-month program.

The differences between the 10- and 30-month programs were largely due to the higher price levels under the 10-month program. Although strict price rules were used to simulate loan behavior, simulated effects of extending loan

maturities should be reliable indicators of real world effects. Extending the time to loan maturity resulted in a lower price level for a given loan rate, less overall loan activity, lower CCC stocks, and a larger portion of loan program controlled grain being in farmer hands.

Comparison of 30-month Program with Act of 1973 Provisions

The 10-month program will not be considered in this section in order to simplify the comparison of the target carryover program with the 30-month loan maturity with 1973 Act provisions. Applicable target prices, loan rates, and CCC release prices are summarized in Table 4.

Prices

The average price levels for the grains, cotton, and cattle and calves are all higher under the 30-month program compared to Act of 1973 provisions. However, maximum prices for the 30-month program are 12 cents less for corn (feed grains), 31 cents less for soybeans, and 2 cents per pound less for cattle and calves while only 1 cent higher for wheat and 1.3 cents higher for cotton (Table 3). The 30-month program shows higher average prices and generally lower maximum prices.

Using the coefficient of variation as a measure of price variability results show the 30-month program reduced variation in corn price by 15 percent, wheat price by 9 percent, soybean price by 15 percent, cotton price by 11 percent and cattle and calves price by 4 percent (Table 3).

Net Farm Income

Net farm income under Act of 1973 provisions ranged from $14.9 billion to $39.8 billion. Under the 30-month program the range narrowed slightly to be between $15.7 billion and $39.2 billion. The average income for all situations for the 30-month program was $139 million higher than the Act of 1973 average (Table 3). Income variation was reduced 9 percent under the 30-month program.

Government Payments

A fixed government payment level of $700 million per year was included in all three programs as an estimate of disaster, other support, and conservation payments. POLYSIM calculated any deficiency payments (1973 Act) or set-aside payments (30-month program) that would be expended and added these payments to the $700 million.

Average annual deficiency payments under the Act of 1973 were $431 million in comparison to average annual set-aside payments under the 30-month program of only $83 million. Average annual CCC operation costs under the Act of 1973

TABLE 4

Target Prices, Loan Rates, and CCC Release Prices

Item	1976	1977	1978	1979	1980
Target Prices Act of 1973:	--Cotton ($/lb.);		other crops ($/bu.)--		
Corn ($1 bu.)	$1.57	$1.65	$1.65	$1.66	$1.70
(CCC release price)....	(1.81)	(1.90)	(1.90)	(1.91)	(1.96)
Wheat ($1 bu.)...........	2.29	2.46	2.46	2.51	2.52
(CCC release price)....	(2.63)	(2.83)	(2.83)	(2.89)	(2.90)
Cotton ($1 lb.)..........	0.43	0.46	0.47	0.47	0.50
(CCC release price)....	(.49)	(.53)	(.54)	(.54)	(.58)
Loan Rates Act of 1973:					
Corn	1.25	1.25	1.25	1.25	1.25
Wheat	1.50	1.50	1.50	1.50	1.50
Soybeans	2.50	2.50	2.50	2.50	2.50
(CCC release price)....	(4.10)	(4.10)	(4.10)	(4.10)	(4.10)
Cotton	0.37	0.40	0.41	0.42	0.41
Loan Rates 30-month and 10-month Progs:					
Corn - Lower Limit	1.37	1.38	1.42	1.47	1.54
Upper Limit	2.54	2.55	2.64	2.73	2.86
(CCC release price).....	(2.92)	(2.93)	(3.04)	(3.14)	(3.29)
Wheat - Lower Limit	1.73	1.62	1.67	1.74	1.80
Upper Limit	3.73	3.15	3.25	3.39	3.50
(CCC release price).....	(3.88)	(3.62)	(3.74)	(3.90)	(4.03)
Soybeans - Lower Limit....	2.67	2.68	2.76	3.12	3.37
Upper Limit....	5.95	5.98	6.15	6.95	7.50
(CCC release price).....	(6.84)	(6.88)	(7.08)	(8.00)	(8.62)
Cotton - Lower Limit	.379	.39	.41	.43	.45
Upper Limit	.495	.51	.53	.56	.59
(CCC release price).....	(.57)	(.59)	(.61)	(.65)	(.68)

were nil, but averaged $27 million under the 30-month program. Total average annual government outlays under the Act of 1973 were $1,131 million. The comparable total was $809 million for the 30-month program. The largest value simulated for total deficiency payments was $4,484 million. The largest total for set-aside payments under the 30-month program was $1,155 million less at $3,329 million (Table 3). This reduction in direct farmer payments more than offset the higher CCC operation costs under the 30-month program which reached a maximum of $212 million. Variation in total government payments was reduced by 48 percent under the 30-month program.

The results indicated that under the 30-month program farmers received a slightly higher average income, and a larger proportion of this income came through the market place.

Ending Year Carryover

The average ending year carryover for feed grains under Act of 1973 provisions was 39.3 million tons. Average ending year carryover for the 30-month program which had a target carryover of 45.0 million tons was 40.5 million tons so carryover adjusted towards the target. The average wheat carryover under the Act of 1973 was 657 million bushels. The average carryover for the 30-month program was 654 million bushels with a wheat carryover target of 600 million bushels. Average cotton carryover also adjusted toward the target. Average soybean carryover was 10 million bushels higher under the 30-month program compared to the Act of 1973 even though the soybean carryover target of 150 million bushels was below the 1973 Act average of 176.7 million bushels. The soybean behavior relates to the large 1975 carryover. The yearly averages for the Act of 1973 show soybean carryover steadily decreasing from 295 million bushels in 1976 to 76.5 million bushels in 1980 (Table 3). Under the 30-month program with a carryover target of 150 million bushels the comparable 1980 carryover is 108.5 million bushels reducing the downward trend but raising the overall average.

The target carryover concept had little impact on carryover minimums. Carryover maximums for the 30-month program were greater by 5 million tons for feed grains and by 150 thousand bales of cotton and were less by 121 million bushels for wheat and by only 1.1 million bushels of soybeans (Table 3). Comparing variation in ending year inventories the 30-month program showed 1.0 percent more variation for feed grains, 6 percent less variation for wheat, 16 percent less variation soybeans and 15 percent greater variation for cotton.

Exports

Average exports under the 30-month program were slightly lower than under the Act of 1973. Except for cotton the maximum export levels were also lower. The reason for the lower exports was the higher price level under the 30-month program. As mentioned earlier, the random export draws adjusted the base export levels allowing deviations from the adjusted level on the basis of price level.

Voluntary Set-Aside Acreage

Feed grain set-aside was used for only 18 percent of the 1500 annual situations for the 30-month alternative. No set-aside was included under the Act of 1973 provisions. Feed grain set-aside acres ranged as high as 38.2 million acres with an overall average of only 1.4 million acres. The year with the highest average feed grain set-aside was 1977 with 2.7 million acres (Table 3).

Wheat set-aside acreage reached a high of 11.4 million acres with an average of less than a million acres. The year with the highest average was 1980 with nearly a million acres. Wheat set-aside was used in only 16 percent of the yearly situations.

No set-aside was needed for soybeans and there were only 13 instances in 1500 situations where cotton set-aside was used. The largest acreage of cotton set-aside was nearly two million acres.

Set-aside, though seldom needed, was obviously a factor explaining the modest improvement in price and income variation noted for the 30-month program.

Outstanding Loans

In the case of the 30-month program farmers could have outstanding loans for crops from three successive years. Under the Act of 1973 an outstanding loan could extend to the next crop year but would mature in that year. The lower loan bounds for the 30-month program are higher than the loan rates specified for the Act of 1973. Loan rates under the 30-month program could be as high as the upper bound which reflected average total per unit production cost. The 1973 Act loan rates, except for cotton, were fixed at a constant level (Table 4).

The total amount of loans outstanding at any one time under the 30-month program ranged from a low of zero for all crops to 18.7 million tons for feed grains, 170.7 million bushels for wheat, 161.5 million bushels for soybeans and 1.24 million bales of cotton (Table 3). There were no outstanding loans in 49 percent of the yearly situations for feed grains, 79 percent of the situations for wheat, 84 percent of the situations for soybeans, and 77 percent of the situations for cotton. There were no loans outstanding over 98 percent of the time under the Act of 1973.

As is apparent from Table 3, some of the outstanding loans were redeemed instead of being delivered to CCC. The implication is that farmers were able to redeem the loan and realize a net per unit value that was greater than the value of the unit delivered to CCC. The outstanding loans serve as a buffer

stock since the farmer is guaranteed a net per unit value while waiting to take advantage of a strong market that will raise price above redemption price. Each farmer will in reality have his own redemption price, rather than a strictly calculated redemption price as was used in the analysis. Further consideration needs to be given to the degree of market stabilization or de-stabilization that the existence of outstanding loans would provide. Because loan rates are variable, outstanding loans from successive years may have different net delivered values and different redemption prices as well. Farmers may redeem a loan taken out in a particular year while keeping other outstanding loans due to different loan rates.

CONCLUSIONS

Evaluation of the 30-month Program

The analysis emphasized specification of a market orientated commodity program for U. S. Agriculture. A policy simulation model was used to illustrate the overall operation and effect of the proposed program and for perspective, the results were compared with a program that was based on continuation of Act of 1973 provisions.

In general the 30-month program simulation results were not dramatically different from the program specified using Act of 1973 provisions. Differences between the 30-month program and the 10-month program were generally predictable given the relationships specified in NRLOAN, the nonrecourse loan subroutine.

Compared to Act of 1973 provisions, the 30-month program reduced price variation modestly as measured by the coefficient of variation. Net farm income averaged higher under the 30-month program even though average government costs, both direct payments and CCC operation costs, averaged less than under Act of 1973 conditions. A higher percentage of farm income came through the market. The averages, variation, and minimum and maximum values for the consumer expenditure for food measure showed very little difference between the programs.

Relationship of Prices and Carryovers

The research results suggest an important question needing further study. This is a determination of the level of carryovers that will be held in private hands without the use of commodity loans or storage subsidies.

When the Act of 1973 was analyzed stochastically there were situations that led to substantial carryovers yet calculated prices did not fall to or below loan rate levels. Therefore, the simulation analysis showed little loan activity under the Act of 1973. Could wheat carryover grow to 1.2 billion bushels without price falling below \$1.55 per bushel, which was still \$0.05 per bushel above the specified loan rate? This was the case in the simulated results. Obviously there would be loan activity as an alternative to private borrowing but to what extent would a loan program encourage additional carryover

when market prices remained above the loan rate?

No clear advantages were apparent for any one of the program alternatives examined in this analysis. If, however, the relationship between non-loan carryovers and price levels were not correct then an adjustment of these relationships would be expected to affect the results and make the contrast between the programs more pronounced.

Another area needing additional understanding and research is the relationship between demand for loans and the market price. The loan subroutine used a calculated breakeven criteria for loan demand. This criteria did not recognize expectations.

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ANALYSIS OF A GRAIN RESERVE PLAN

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ABSTRACT

This paper develops a specific proposal for grain reserves. By examining past experiences and the evolving role of the U.S. in world grain markets, it identifies four purposes of reserves. First, grain reserves should function like shock absorbers--rising and falling as needed--rather than as a perennial grain inventory insulating the U.S. from events in world markets.

Second, reserves should be carefully insulated from the market to avoid premature release on the one hand and distortions of market forces on the other. Third, reserves should be held to meet needs arising from inevitable but unforeseeable fluctuations in supply or demand. Finally, reserves should reinforce market forces by placing clear limits on governmental actions to eliminate needless uncertainties.

A reserves proposal meeting these standards would include the following provisions: agreement on specific total carryover objectives; acreage adjustments to bring actual carryover levels to these objectives; government ownership of a specific proportion of total carryover objectives; governmental acquisition and release of stocks at specific, known prices separated by a wide band.

INTRODUCTION

The notion of a reserve supply of food is an ancient and logical one. Yet, it has proven emotional and divisive, often because confusion about what is meant clouds many discussions.

This paper examines a very specific proposal for grain reserves. That proposal would authorize the U.S. government to purchase grains under certain conditions. It would also prevent the U.S. government from releasing those reserve grain stocks except under certain conditions.

The basic purpose of this reserves plan is to provide assurance of supplies to users of U.S. farm products--both domestic and foreign customers. It would preserve the essential strengths of an open, competitive grain marketing system in most circumstances while guaranteeing availability of grain stocks to meet extreme needs.

WHY HOLD RESERVES

For most of the period since World War II the United States has been concerned mainly with the problems of grain surplus. From 1950 to 1970 world grain production increased steadily. Large carryover stocks accumulated, with the United States and Canada holding most of them.[1] In these circumstances there was little interest expressed in grain reserves.

No doubt one reason was that domestic U.S. grain prices remained within a very narrow range defined by government programs. The floor in that range was the price support level at which government acquired grain stocks through

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[1] U.S. grain stocks peaked in 1961 at 115.5 million metric tons. Canadian stocks that year of 21.1 million tons meant that the two nations combined held 76 percent of total world grain stocks. That share has been halved to 38 percent today.

default under its commodity loan programs. The ceiling in that range tended to be defined by the resale formula for government-held stocks.[2]

This pattern began to change in 1970, as indicated in the following table. Between 1970 and 1973 world grain stocks fell 60 million metric tons--or nearly one-third--while consumption grew 70 million metric tons. Much of this stock reduction represented a conscious policy effort in Canada and the United States to eliminate burdensome surpluses. For example, the United States did not discontinue its wheat export subsidy until September 1972, enabling the Soviet Union to purchase about 10 million metric tons of U.S. wheat before world prices fully reflected the tighter supply conditions which had emerged.

TABLE I

WORLD: TOTAL GRAIN SUPPLY-DISTRIBUTION MKT. YRS.

1969-70 through 1975-76

	Beginning Stocks A/	Prod.	Total Exports B/	Consump. Total
	-----------------Mil. Mt.--------------------			
1969-70	188.1	832.1	102.4	852.0
1970-71	168.2	832.7	109.6	870.4
1971-72	130.5	920.0	114.1	902.8
1972-73	147.7	899.3	141.4	938.9
1973-74	108.1	976.6	150.3	974.7
1974-75 Prel.	110.0	920.9	137.6	930.8
1975-76 Proj.	100.1	915.2	150.0	920.0
1976-77 Proj.	95.3			

A/ Represents aggregate of local marketing years and does not represent world stock levels at a fixed point in time. Numbers underestimate actual stocks as data is not available for all countries.

B/ Data based on aggregate of local marketing years and therefore differ from July-June data.

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[2] That formula authorized the Commodity Credit Corporation to sell from its stocks into the market whenever grain prices reached or exceeded 115 percent of the loan level plus carrying charges.

Carryover stocks have remained low since then. These tighter world grain supplies have raised questions about world food prospects. Some see in these developments a fundamental deterioration in the long term balance between world grain supply and demand. Others, however, see in these events a temporary, periodic imbalance in the grain economy rather than a chronic deterioration in food supplies.

Studies by the Food and Agriculture Organization, the Economic Research Service of the Department of Agriculture and Iowa State University all tend to support the latter view. They agree that, for the next decade at least, the world should be able to produce enough food to meet its rising demands.

It also seems likely that world grain production will continue to fluctuate above and below rising consumption. In some years competition for commercial export markets may be intense. In other years strong demand or poor harvests will exert pressure on available supplies.

Reserves are perceived as a means to soften the impact of such cycles. The question still remains: "soften them in what way?" Some advocates of a reserves program appear to favor large grain stocks designed to insulate U.S. consumers from the price fluctuations occurring on world markets. Such an approach could involve not only a return to stock levels characteristic of the 1950's and 1960's but also more frequent use of export controls.

Others recognize the value of reserves but wish to avoid the excessive surpluses and artificially stable prices that characterized the U.S. farm economy in the 1960's. In this view grain reserves would function like shock absorbers, moving up or down as needed. They would be held not to stabilize prices but to provide a reasonable degree of supply assurance. The analysis developed in this paper supports this latter view--reserves as a shock absorber rather than a perennial grain inventory.

HOW TO MANAGE RESERVES

Management of reserves to assure supplies differs sharply from management of reserves to stabilize prices. Stock management policies designed to enforce price stability distort the grain economy in a variety of ways. Their consequences would be similar to the effects of existing farm policies in some other industrial nations.

For example, many traditional customers--like the European Community (EC) and Japan--maintain agricultural and trading systems that insulate domestic grain prices from world developments. As a result their grain consumption does not respond significantly to production shortfalls or changes in world grain price levels.[3]

The European Community accomplishes this through its Common Agricultural Policy and its administration of variable levies. In most years grain prices within the European Community are higher than those prevailing in world markets. The EC protects domestic grain production by adjusting import levies to guarantee a margin of preference for internal production. This discourages grain consumption in the EC, encourages unnecessary grain output and shifts the burdens of surplus onto farmers in major exporting nations.

In years of tight grain supplies the Community has converted its variable grain levies into variable export taxes.[4] The effect has been to hold grain supplies within the Community, artificially encouraging domestic grain use while aggravating the tight supply situation for the rest of the world.

A grain reserves program administered to keep prices artificially stable would have comparable consequences. In years of plentiful supplies large reserve stocks would bear down on grain prices. Government would be pressured to intervene either to support prices or to maintain farm incomes through direct payments. These actions, in turn, would tend to encourage continued unnecessary grain output.

In years of poor crops or high demand, attempts to preserve stable prices would require moving grain out of stocks and into consumption before prices rise. The effect would be to subsidize grain use instead of reducing marginal

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[3] For example, EC grain production plus net imports between 1972-73 and 1974-75 remained remarkably stable, fluctuating about 2 million tons or less than 2 percent. In the same period U.S. domestic wheat use varied 100 million bushels (or 13 percent) and coarse grains 38 million short tons (or 22 percent).

[4] As world grain prices rose the EC variable levy declined, eventually reaching zero in December 1973. Subsequently it became a variable export tax.

consumption. In many years, this artificial regime of low prices and high grain use could only be maintained through political rationing--probably export controls.

If export controls are imposed in order to prevent this drain on stock levels, the U.S. reputation as a reliable supplier would be damaged. The costs of this are difficult to identify and assess, but they are quite large.

Currently, domestic users consume about 70 percent of U.S. grain production. Approximately 60 percent of U.S. wheat, half of America's soybeans and one-quarter of its corn output depend upon overseas markets. Those export have trebled in value over the last five years and nearly doubled net farm income. They have become a major contributor to the U.S. balance of payments, strengthening the dollar and reducing the cost of imports to domestic consumers.

The potential costs arise from the fact that these overseas markets are not immutable or certain. Grain imports serve residual food needs in the world, and U.S. grain exports account for only 5 percent of total world grain consumption. Given enough concern nations could develop alternative sources of supply, either by expanding their own internal production at higher cost or by seeking out alternative sources for imports. For example, following the 1973 U.S. soybean embargo Brazilian soybean production expanded sharply--rising from 5 million tons in 1973 to an estimated 11.3 million tons this coming year. Its exports are already cutting into U.S. soybean markets.

Very simply, to build and hold these valued overseas markets the United States must be prepared to supply the needs of its foreign customers in bad years as well as good. It cannot assume that its foreign customers need its grain imports more than the U.S. needs these markets. A policy to maintain undue price stability in domestic grain markets necessarily will divert resources from optimal investment patterns to meet world food needs while endangering needed, valuable overseas markets.

A grain reserves policy need not involve these adverse consequences. If reserves are held and managed to moderate the effects of unanticipated developments, they can provide reasonable supply assurance while reinforcing normal commercial relations. Price changes would continue to signal needed adjustments in production and consumption. In order to do so, however, prices must be permitted to

move over sufficient range to attract resources and discourage consumption in years of tight supplies while discouraging production and encouraging grain use in years of plenty.

The capacity of grain markets to make such adjustments should not be under-estimated. For example, in the face of poor feed grain crops in 1974-75 the U.S. reduced its grain consumption some 30 million tons. No doubt this adjustment was painful--mainly because it represented four-fifths of the reduction in grain use for the world as a whole. Yet, it demonstrated that consumption adjustments could be made to accommodate a temporary supply imbalance. In effect, it demonstrated that feeding of grain to livestock represents an important secondary food reserve.

Moreover, the burdens of adjustment would have been much smaller had they been shared--rather than aggravated--by policies among our major foreign customers. The burdens also could have been moderated had there been a mechanism in place to hold reserve grain supplies off the market until this process of reducing consumption was well underway.

WHO SHOULD HOLD RESERVES

Even those who recognize the value of holding reserves to assure supplies rather than to freeze prices within a narrow band will disagree about who should hold them. Some believe that such stocks should be held by private parties--farmers, processors and merchants.

There is no doubt that private parties will hold some grain stocks. A certain amount of grain must be flowing through commercial marketing channels in order to meet pipeline needs and ensure continued operations. It also appears that the amount of grain private parties would be willing to hold in this manner increases as the government withdraws from the marketplace. Increased price volatility enhances the opportunity to foresee increases in market prices and profit from them.

Privately held grain stocks, however, do not constitute conscious, managed reserves. Private stocks are held to meet foreseeable events. The value of reserves to society, by contrast, comes from their availability when the unexpected arises. Conscious reserves then, are held to meet the unanticipated, the unforeseen.

At the other extreme some have argued that reserves should be internationally owned and managed. Such an approach has the advantage of sharing costs and administrative responsibilities for world food stocks.

It also has a number of disadvantages. It surrenders control over stocks even though the United States accounts for fully half of world grain exports. There is also the risk that international stocks would be handled in ways damaging to U.S. interests, perhaps seeking to hold grain prices too high or, alternatively, using reserves as a means of disposing of unwanted surpluses. Finally, it is still unrealistic to expect to achieve the degree of international cooperation needed to make such a program work.

The third alternative--and the one supported by this analysis--is to authorize the United States government to hold limited grain stocks as designated, conscious reserves. This would preserve control of reserve grain supplies in U.S. hands, insuring that those stocks are used to advance vital national interests. At the same time, in contrast to private ownership it provides the opportunity to assure supply availability. Only the government is in a position to withhold grain supplies from the marketplace until it is determined that those reserves are needed to meet broad public interests.

There remain, however, some problems with government ownership of reserves. For example, pressure from urban political interests could induce government to use reserves to hold prices artificially low and stable. This concern and the experiences of the 1960's seem to account for widespread opposition to reserves by farmers.

There is also the risk that government would handle reserve grain supplies in order to achieve short term economic or political objectives. The resulting uncertainty over governmental action could well aggravate price movements at both high and low ends.[5]

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[5] For example, pressure for imposition of export controls on wheat intensified during the winter of 1973-74. Between November 23, 1973 and February 24, 1974 wheat prices rose from $4.80 to $6.35--or $1.55 per bushel. As the U.S. entered the spring it became clearer that it did not intend to impose export controls. Between February 24 and May 19, 1974 wheat prices fell $3.00 per bushel. During this total 6 month period, USDA revised its export estimate upward 50 million bushels--hardly enough to account for this price volatility.

To avoid these risks specific limits should be placed on governmental actions. Government should function only as a residual buyer and seller of grains. Where normal market activities could accommodate needed adjustments, governmental activity should be ruled out.

HOW SHOULD GOVERNMENT HOLD RESERVES

At least three distinct alternatives are available to government in holding grain stocks. First, it could continue past arrangements. The Commodity Credit Corporation would acquire grain stocks through default under the loan program. Those stocks would then be available for resale for unrestricted use at some modest margin over their acquisition cost.

There are several difficulties with this approach. First, acquiring stocks for the reserve through defaults on loans in effect forces farmers to bear an undue proportion of the costs of providing reserves.

Raising loan levels could ease this burden, but it would create other problems. If price support levels are raised too high, grain prices cannot fall sufficiently to encourage additional consumption. Excessive grain stocks would accumulate in governmental hands rather than be cleared from the marketplace.

At the same time unduly high price supports would encourage competitive grain production abroad. By ensuring producer returns high price supports encourage overseas farmers to make capital investments they would be reluctant to make under a regime of greater price uncertainty and wider price fluctuations. One of the major deterrents discouraging competitive foreign production is the knowledge that U.S. farmers will meet market competition.

The other serious difficulty with this approach is that the old price band was much too narrow. A narrow price band increases the risk that reserves will be sold prematurely--that is, before some necessary and relatively easy adjustments in consumption have been made. To reduce this risk by increasing the size of reserve stocks increases their costs. Larger reserves would cost more to acquire and more to carry from year to year. There would also be the additional costs to society from wasting scarce resources on excessive price stability.

For all of these reasons the existing farm program appears to be an unfair and unduly expensive means of acquiring and releasing reserve stocks. The tools for acquiring and releasing those stocks are clumsy and introduce distortions that cannot easily be eliminated.

A second approach would tie governmental acquisition and release of reserve stocks to specific "quantity triggers". For example, if projected production fell a certain percentage below trend, government would release stocks. Similarly, if projected production exceeds trend by a particular percentage, government would acquire grain and increase its stocks.

This approach represents a distinct improvement. It ties acquisition and release of stocks to imbalances in supply and demand.

There are, however, a number of problems in this approach as well. First, it focuses on the supply side of the equation. Yet, as experiences in 1973-74 indicated pressures on grain stocks can come from demand developments as well. Though world coarse grain carryover stocks were relatively low at 57.2 million metric tons, coarse grain consumption increased nearly 40 million metric tons that year, and exports--already at a record level the preceeding year--increased nearly 15 percent. It is difficult to see how quantity triggers could take into account both supply and demand developments without becoming hopelessly complex and uncertain in their administration.

In addition, quantity triggers--at least those tied to projected developments--risk premature release of grain stocks. Urban political pressures, no doubt, would aggravate this tendency. Efforts to minimize this risk could quickly involve acquisition of excessively large stocks or use of more draconian measures like price or export controls.

Finally, a system of quantity triggers introduces unnecessary uncertainty into the marketplace, and uncertainty about likely governmental action leads to inequities. Parties who chose one course of action in anticipation of quantity triggers could be surprised and injured when a revised outlook alters government plans. Actions based on projections rather than guided by actual supply and demand developments also could contribute to misallocation of resources, including

delayed consumption adjustments and misinformed planting decisions.[6]

The third alternative--and the one supported by this analysis--would determine the levels at which government could acquire or release stocks through known, specific price triggers. The price triggers should be established in the law and revised only periodically. Representing a careful, thoughtful balancing of producer and consumer interests, they would be secure against short-sighted attempts to modify them in response to either rural or urban pressures.

At the same time use of specific, known price triggers would remove the major uncertainties characteristic of quantity triggers. Establishing fixed limits on governmental actions should promote market activities directed at resolving grain problems.

This is an important point. The market's ability to adjust consumption in the near term and to trigger appropriate production changes in the following crop year is the most powerful and useful tool available to correct supply imbalances. The reserves program envisioned here would reinforce rather than retard these market forces. This can be illustrated by a few examples.

If grain prices fell toward acquisition levels, private entities would be on notice that government could soon come into the market to buy grain. Since that grain would then be held off the market until prices had risen significantly, private buyers would be encouraged to increase their own purchases and lengthen their pipeline stocks. This would draw excess supplies into consumption channels while buoying prices at the lower side.

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[6] Neither of these effects should be underestimated. U.S. coarse grain consumption, for example, declined nearly 25 percent in 1974-75, more than was initially projected. The value of timely, accurate production signals, on the other hand, is illustrated in the degree to which planting intentions have changed from year to year since 1970. For example, acreage planted to wheat jumped from 59 to 71 million acres between 1972 and 1973 in response to a doubling in price. Price increases for corn and soybeans were more moderate, as were their acreage adjustments. Strong wheat and corn prices have continued to attract acreage, but area planted to soybeans has declined nearly 6 million acres as a result of comparatively weak soybean prices.

Similarly, the knowledge that grain could not flow out of governmental stocks into private marketing channels below predetermined prices would remove the fear that governmental release of stocks would undercut efforts by domestic buyers to cover their needs. Domestic buyers would be free to make timely grain purchases. And, availability of extra stocks once prices exceed that level would reduce the pressure on foreign buyers to purchase more than actual consumption needs in order to insure against export controls.[7]

Instead, normal marketing mechanisms would continue to function and in many cases would function better, since uncertainties about governmental actions would be resolved over a wide price range. Under these circumstances grain users could more intelligently plan their purchases and consumption, and grain farmers could more intelligently allocate their land and capital among alternative crops.

THE SIZE OF STOCKS AND WIDTH OF THE PRICE BAND

The size of grain stocks and the width of the price band are obviously interrelated. Maintenance of a relatively narrow price band requires relatively large reserve stock quantities. This means higher costs for acquiring and holding reserve stocks. It also means less

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[7] The importance of eliminating this uncertainty is perhaps best illustrated by events in the wheat economy in early 1974. During that period there was much popular discussion of bread rising to $1.00 a loaf. Domestic millers and bakers were anxiously pressing government to invoke export controls to protect domestic wheat supplies. Uncertainty over governmental actions appeared on the one hand to encourage foreign buyers to increase their export purchases, pushing wheat prices up further. They were motivated to purchase above immediate consumption needs to protect themselves against the risks of controls--like those imposed on soybean exports in 1973--that reduce actual shipments. On the other hand domestic mills apparently deferred grain purchases in the hope that export controls would cut their raw material costs or at least out of fear that export controls--by reducing domestic prices--would make them uncompetitive with domestic mills which did not cover their needs until after controls were imposed.

freedom for market forces in guiding consumption and production decisions as well as long-term allocation of capital resources.

Moreover, it means a more active role for government in the grain economy, since a narrow price band means more frequent governmental forays into the market either to acquire or to release stocks. Finally, a narrow price band and large U.S. stocks enable other nations to allow the burdens of stock management to be borne by the United States.

A wider price band between acquisition and release of reserve stocks reduces the size of stocks needed to meet most supply imbalances. Instead, interim adjustments in consumption levels and longer-term adjustments in production levels would bear a larger share of the burden of meeting supply imbalances. As a result the cost of holding and managing reserve stocks would be smaller.

Modest U.S. stock levels and a wide price band would exert greater pressure on other nations to assume a larger share of the burdens of maintaining grain stocks. It would also promote more responsive marketing actions. For example, as grain prices fell toward acquisition levels, importers would be encouraged to make additional grain purchases and lengthen their own pipeline stocks, since any stocks purchased by the United States government would not again be available in the marketplace until prices had risen sharply.

Similarly, the assurance of availability of specific stocks at known release prices would counteract the psychology of hoarding grains as prices rise. Importing nations would be more willing to limit their purchases to current consumption requirements.

The size of reserve quantities and the width of the price band must be determined by carefully balancing conflicting interests. Consumers, processors and livestock and dairy producers have an understandable desire to see grain prices remain stable. Grain farmers, on the other hand, benefit from high grain prices, and there is some evidence they also benefit from price instability. Taxpayers wish to reduce as much as possible the costs associated with holding grain stocks. Finally, the U.S. as a nation benefits when the burdens of holding stocks are shared more broadly and equitably among countries. The U.S. also benefits under a system that permits foreign exchange earnings from farm exports to be maximized in the short term and to grow over time.

Balancing these conflicting interests depends on the willingness of all parties to compromise. No one group can expect to be the dominant beneficiary or to bear an undue share of the costs of the program. Analyzing stock levels and price bands against past experience can help identify the costs of different alternatives and suggest an appropriate compromise.

World wheat stocks have fluctuated over a range of about 25 million tons in the past five years, falling from about 20 percent of consumption to about 14 percent of consumption. Virtually all of the reduction in stocks occurred in 1972-73, when U.S. surplus grains could re-enter commercial channels from Commodity Credit Corporation stocks at 115 percent of loan levels plus carrying charges. During this five-year period world wheat consumption fluctuated over a range of 20 million tons. This suggests that world stock levels themselves may well have been adequate but that the narrow price band maintained early in the period permitted too much consumption at relatively low prices.

World coarse grain stocks in the same period fluctuated over a range of about 37 million tons. Production and consumption each changed about 50 million tons, suggesting that world feed grain stocks may have been too small. Counter balancing this, however, is the fact that consumption of feed grains by livestock can be more easily adjusted without threatening human food supplies. The difficulty, again, seems to have arisen from the fact that stocks moved into consumption <u>too early</u>.

U.S. wheat stocks fluctuated over a 17 million ton range, and U.S. feed grain stocks moved over a 25 million ton range. Since U.S. grain exports currently make up about half of total world grain shipments, it seems clear that the U.S. carried more than a proportional share of the burden in adjusting to changing supply and demand conditions. A conscious reserve stocks program should help adjust this burden-sharing more equitably.

A SPECIFIC PROPOSAL

This analysis suggests the following reserves program:

(1) government would be authorized to buy and hold in an isolated reserve the following quantities:

250 million bushels of wheat
12.5 million tons of feed grains
75 million bushels of soybeans

(2) government purchases would be made at levels below long-term equilibrium prices but above price levels forcing resources to leave farming. Acquisition prices might be in the neighborhood of $2.25 for wheat, $1.75 for corn and $4.00 for soybeans. These would not necessarily be price floors, and surpluses above levels targeted for the isolated reserve could push prices lower;

(3) when government acquires stocks equal to the isolated reserve carryover objectives, the Secretary of Agriculture would cut back acreage. When stocks are below the targeted levels, the Secretary would increase acreage.

(4) the government would not be permitted to release stocks at less than two times acquisition prices. For purposes of illustration the price band might be 2.5 times acquisition:

Wheat	$5.63	(2.5 x $2.25)
Corn	$4.38	(2.5 x $1.75)
Soybeans	$10.00	(2.5 x $4.00)

If prices reached these release points, the government would have the option to release stocks but would not be required to do so. It is expected that stocks would be released gradually to avoid major price fluctuations.

EFFECTS OF THE PROPOSAL

This approach to reserves would permit modest consumption adjustments while ensuring supply availability in times of extreme need. It would also avoid undercutting incentives to farmers to increase production--the only meaningful solution to shortage.

At the same time this proposal authorizes government to hold only limited stocks and requires adjustments in production if surpluses accumulate. This avoids the risk of returning to the burdensome surpluses of the past. In fact, insulating the reserve stocks by a wide price band enables government to make prompt acreage adjustments without endangering grain supplies.

Reserve stocks effectively insulated by a wide price band also reduce the probability that the U.S. would again have to rely on export controls in a period of tight supplies. Such a reserve would reinforce the country's reputation as a reliable supplier of grains in the world market.

Yet, the relatively wide price band should reduce the likelihood that the U.S. will have to carry an excessive share of world stocks and should increase the chances that others will assume a larger share. Importing nations especially will either have to assume some of the burden of carrying stocks or be more willing to adjust their consumption to changing supply and demand conditions.

In summary, a conscious grain reserves program should ease supply and demand adjustments, not impede them. U.S. grain reserves should function like shock absorbers, rising and falling with grain needs. The reserves should be clearly insulated from the marketplace until needed. They should not be designed to insulate the domestic economy from its world counterpart.

Finally, they should reinforce market adjustments, recognizing the essential strengths of the marketplace in most circumstances while ensuring availability of supplies for periods of real need. They should not function to replace price discovery through the interplay of supply and demand, nor should they encourage concerns and uncertainties about governmental interventions.

A CONCLUDING COMMENT

Food security depends not only on reserves but also on other food and farm policies. In particular, liberalization of agricultural trade continues to be an important objective in periods of tight supplies as well as in periods of ample supplies. Freer farm trade would broaden the consumption base on which adjustments to production variations could take place.

Structuring international grain flows on the basis of more open trading rules makes good economic sense to grain exporters like the U.S. But, it would also benefit grain importers by lowering their food costs over time. Their reluctance to move in this direction reflects complex internal social, political and economic forces.

Their decision to subsidize their domestic farm production, however, is made easier by concerns over supply availability. Trade-inhibiting measures simply follow as a means of supporting that policy. Free trade in grains would provide supply assurance at less cost. By freeing up market forces yet assuring supplies when needed, a reserves program like the one outlined here could prove a useful bridge from current circumstances to a more liberalized trading world.

ACKNOWLEDGEMENTS

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GRAIN SALES AND PRODUCTION CYCLES

A COMPUTER SIMULATION STUDY

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This paper compares the likely outcome of the recently completed negotiations between the United States and the Soviet Union for the sale of American grain with a similar large purchase which took place in 1972. The study concludes that: 1) the behavior of the U.S. grain production system is characteristically cyclical, although the oscillations can be significantly reduced by maintaining a suitable reserve stock; 2) the effect of any large grain sale is dependent upon when it occurs during the production cycle; and 3) since the 1975 sale comes at the peak of a production cycle, the system response will be attentuated and the grain sale is therefore desirable at the present time.

INTRODUCTION

> "No longer is the United States a residual supplier holding an umbrella over world food prices. Our surplus is gone, and our inventories are low. We realize that we must be competitive in world markets and that we cannot offer our inventories as protection for the pricing policies of other exporting nations."
>
> Ray A. Goldberg (1)
> Co-Chairman of the Panel on Nutrition and Food Availability for the U.S. Senate Committee on Food and Nutrition

In October 1975, the United States and the Soviet Union completed an agreement for the sale of nearly 18 million tons of grain during the current marketing year. The pact also provided for the sale of six to eight million metric tons annually for the ensuing five years.

This agreement came just three years after a similar large Soviet purchase that greatly depleted the American granary. When 1973 production was less than expected due to inclement weather, domestic wholesale food prices rose by nearly 56%. The shortage was further exacerbated by a disastrous 1974 crop year. Weather losses, especially in the wheat crop, were the worst in decades. Corn output was down by 18% from 1973 levels (down 31% from forecasts). All this happened, in spite of an all-out effort to increase production.

Needless to say, when agricultural negotiations between the USSR and the US were announced in September 1975, apprehensions were high in Washington and across the nation. A.F.L.-C.I.O. President George Meany (who instructed affiliated dock workers to refuse to load ships bound for Soviet ports) was among the most vociferous critics of the negotiations. Meany feared that the 1975 agreement would result in another giant rise in the consumer price index for food in the United States. At the

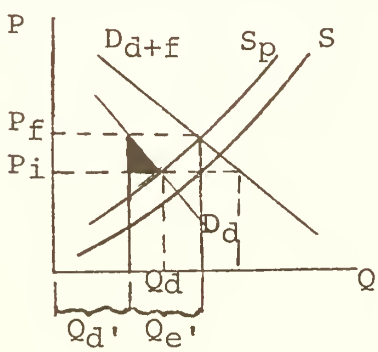
same time, Agriculture Secretary Butz argued that the U.S. must stimulate export sales to maintain farm incomes and to earn foreign currency badly needed to finance the expected balance of payments deficit. Farm products provide nearly 25% of all U.S. export earnings annually.

With world grain inventories below 100 million metric tons (less than one month's supply), the United States must urgently evaluate its export policies. Not only do our export policies affect world hunger, but they also impact upon 1) the balance of payments, 2) domestic prices, 3) foreign relations, 4) internal prices and production levels in foreign countries, 5) farmer incomes and, as a result, future food production. It is difficult to rank these effects by level of importance and to establish consistent export programs since some of the issues are in mutual conflict. However, thorough analysis could provide a better understanding of the interaction between the issues, could help in the formulation of a satisfactory export policy, and help settle the internal debate.

ANALYSIS

Before drawing any conclusions about the likely inmpact of the 1975 grain sale, we must first understand the current state of the system. Toward this end, let us examine the three possible configurations of the major system variables using supply and demand curves to trace the behavior of the system during one production period.

EXHIBIT 1: D>S

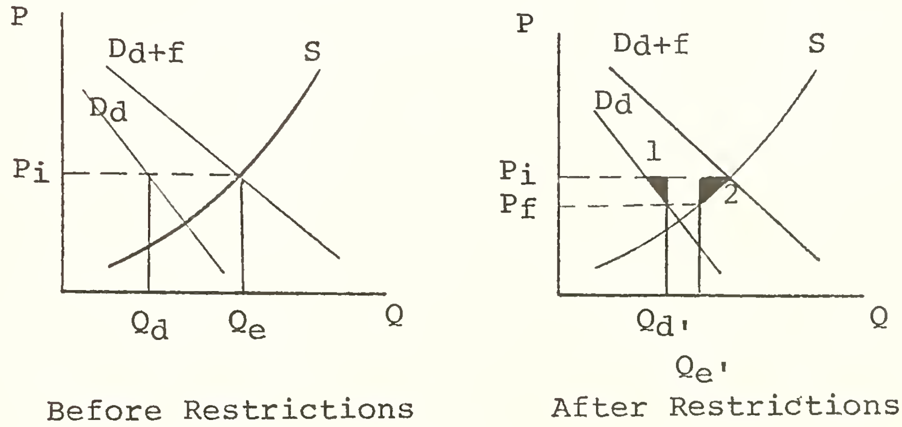


P_i= Initial Price
P_f= Final Price
Q_d= Initial Domestic Consumption
$Q_{d'}$= Final Domestic Consumption
$Q_{e'}$= Final Export Demand
D_d = Domestic Demand
D_{d+f} = Domestic + Foreign Demand
S_p = Poor weather supply

In Case I, total demand exceeds the supply of grain at

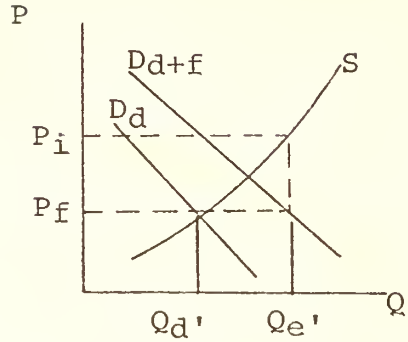
Pi. To meet total demand (Dd+f), price must rise from Pi to Pf, because after the harvest, supply is fixed at Qd'+Qe' and inflationary pressures would increase. This price rise would cause domestic consumers to forego an amount of grain consumption equal to Qd - Qd'. In this case, farmers would enjoy high prices and, due to the inelasticity of export demand, increased revenues. The consumer clearly pays a great percentage of the costs (represented by the shaded region). This case represents the fears of George Meany. If such a condition actually existed, and we were most concerned about consumer prices and domestic inflation, the export sale should be avoided.

EXHIBIT 2: D=S



In Case II, Pi is sufficient to stimulate production of a supply capable of meeting total demand. Clearly, in this case, the USDA should not intervene and should allow the markets to allocate the supply efficiently between domestic and foreign markets. If export restrictions were imposed, the price would drop from Pi to Pf, and farm revenues would decline. Shaded area (1) represents the additional wheat which would be purchased domestically were export restrictions imposed. The net result would be that consumption expenditures would be mis-allocated to the grain sector from other competing sectors of the economy. Shaded area (2) represents export revenues lost to farmers. In this case, the most severe consequences would be felt abroad, since foreign countries would be forced to shift grain from livestock feed to direct consumption to meet their shortfall. In less-developed countries, the consequence might be a serious food shortage and lower per-capita consumption of calories and protein.

EXHIBIT 3: S<D



In Case III, where the supply exceeds the total amount demanded, price would have to fall from Pi to Pf in order to sell all of the production surplus. As the price falls, so would farm revenue. Here, efforts to stimulate demand, (that is, shift the demand curve to the right) for example, similar to a long-term grain sale package might be desirable to keep farm revenues from falling dramatically. In this case, foreign and domestic consumers would enjoy a lower price, but farmers, already in a tight credit squeeze, would stand to default on many loan payments if suitable prices were not maintained. This issue is of prime concern to Secretary Butz. Since increased trade imbalances might also prove to be controversial in an election year, a grain sale would be justified.

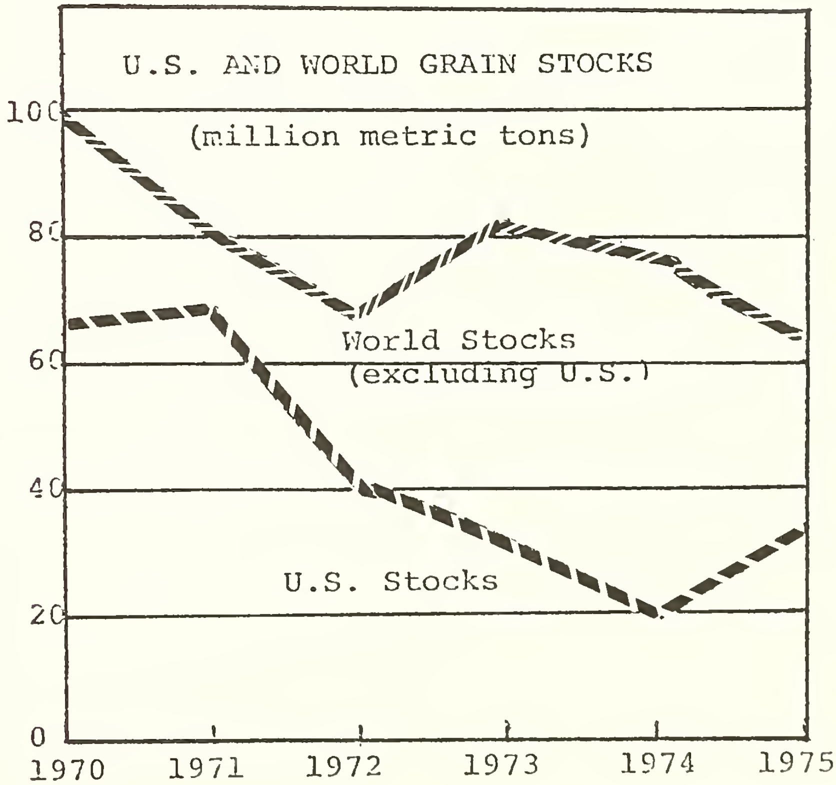
The preceding analysis, like much of the current debate, focuses only on short-term price levels and on policy decisions which optimize current-year marketing statistics. This approach overlooks several vital factors dealing with the longer-term dynamics within the grain system.

The short-term analysis yields no information on the secondary and tertiary effects of a grain sale. Although a supply-demand analysis can be used to determine with reasonable accuracy the short-term effects of a grain sale, it does not permit an accurate long-term prediction of future prices. Since variables in the supply and demand sectors are interrelated, a change in any one of the variables will have consequences throughout the entire wheat system over time. Any long-term prediction is inherently limited by some basically unpredictable factors like technological growth and weather variation. At the same time, it is influenced by some identifiable regularities which are characteristic of the system, like the manner in which farmers make capital budgeting and production decisions. It is upon these regularities that a model should concentrate. Any modeling effort determined to accurately predict price in the face of such an unpredictable force as weather is bound to fail.

Finally, American agriculture has a limited ability to buffer itself against sudden shocks to the delicately balanced system. After 1974 crop failures, U.S. stocks were at their lowest levels in years (See EXHIBIT 4). The low stock levels are bound to influence price, which then influences future planting decisions. A short-term analysis fails to trace such important behavior patterns over time.

The 1975 crop year was forecast as a record year. Plantings were at record levels for almost every commodity. Even though a summer drought did some damage to the corn crop, the harvest exceeded the forecast. The only question remaining is whether the abundant harvest is sufficient to replenish the reserves and meet the high export demand for American commodities. This paper will also attempt to determine the importance of timing in the analysis of potentially destabilizing grain sales.

EXHIBIT 4



Source: U.S.D.A.

An analysis which focuses on the conditions under which instabilities will occur is perhaps a more reasonable effort. Feedback simulation modeling is well suited for this purpose and much can be learned about the influence of policy variables by an examination of the dynamic behavior of the system over time.

A short-term analysis cannot represent the fact that as the farm price begins to drop, so do producer expectations of future earnings. The producer response to lower price is to cut back on production. The cutback in turn drastically reduces the future supply. This possibility was critical in 1975 because the high prices in 1973 and 1974 caused farmers to borrow heavily to finance the production expansion to 1975's record levels. Many small producers run the risk of going out of business if prices drop substantially. In other words, the supply curve may be expected to shift continually in markets where current output is a function of past period investment decisions. The more distant the past period, the more likely the current market conditions will differ from those which motivated the decision to invest. Economists refer to such an environment as a supply-shift market.

Models which do not deal with the interrelations between all the real-world sectors are limited in their ability to explain long-term system behavior patterns. This author assumes that real-world social systems belong to the category of non-linear integration feedback systems. Two variable types are needed to define the structure of such models. Rate variables define flows of money, grain, and production capacity at a given instant in time. Level variables accumulate those past flows,(i.e. the number of bushels of grain in inventories, or the number of acres under cultivation). Levels are changed only through increases or decreases in pertinent rates. The rate variables are modified by specific feedback relationships. These relationships govern the manner in which real-world players perceive and react to existing market conditions (either economic or social). Finally, these feedback loops often are comprised of non-linear decision rules.

There is also a high degree of variability in yield and production in the prime growing regions of the nation due to the vagaries of weather. We experienced poor crop years in 1973 and 1974 for this very reason. In addition, world-wide weather variability plays a large part in determining foreign demand for US crops. A model with a stochastic representation of weather is useful when one is concerned with system instabilities.

THE MODEL

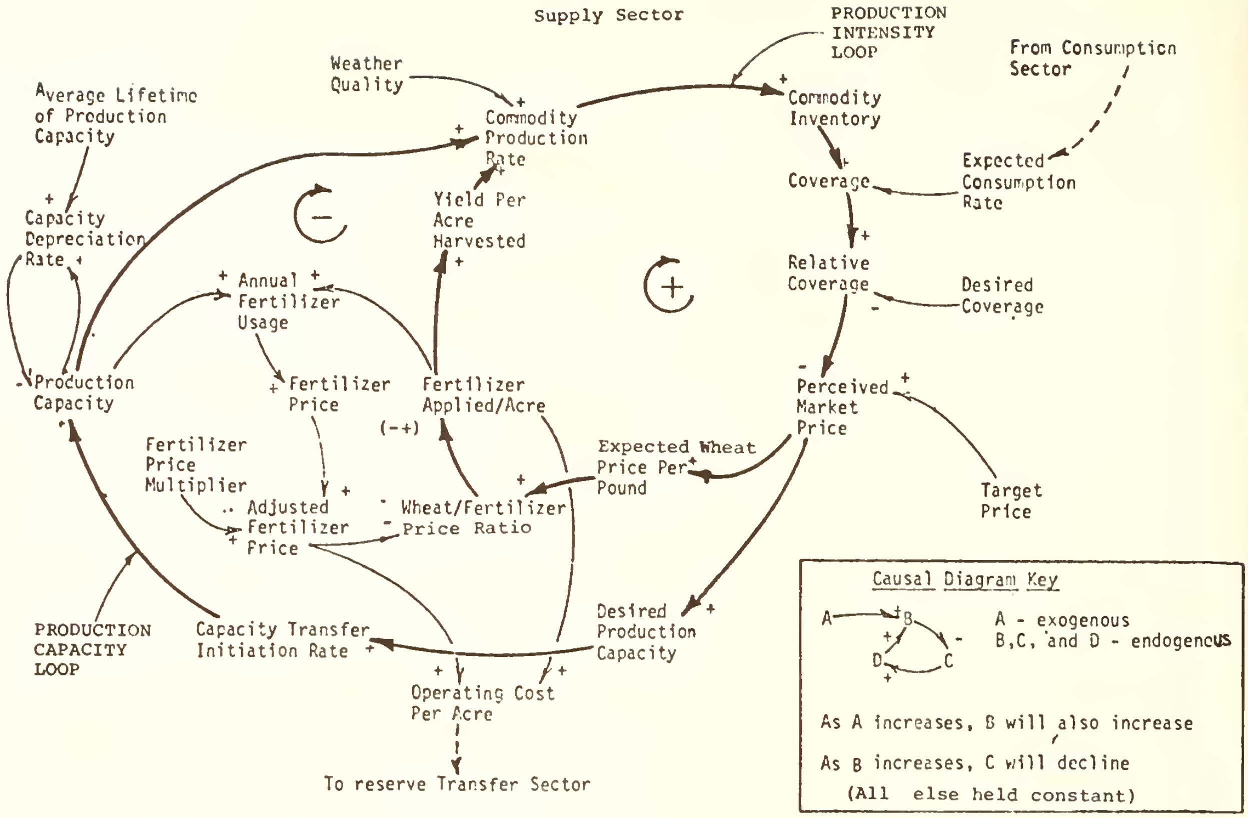
To examine the long-term dynamics of the grain sector, a system dynamics computer simulation model of the U.S. wheat economy has been constructed (Forrester (2)). Structurally, the model is composed of three main sectors; a supply sector, a demand sector, and a farm-program sector. The model can be characterized as what Chambers, Mullick, and Smith (3) refer to as a causal model. It focuses upon the specific relationships between all of the system elements. Assumptions about the relationships in the wheat sector are presented in a Causal Loop Diagram (Exhibit 5). The arrows point from causes to effects. The plus and minus signs indicate the sense of the influence. A positive arrow implies that an increase in the influential variable results in a change in the influenced variable in the same direction, all else held constant. A negative arrow suggests a change in the opposite direction.

1) The supply sector contains two main feedback loops. A basic short-term production-intensity loop represents the fact that farmers can control production by modifying the application of inputs (the most predominant of which is fertilizer). A farmer can meet production goals in two ways. He can plant the number of acres required to generate sufficient output to achieve the goal given the current value of yield, or he can plant fewer acres and farm the existing land more intensively (using more inputs). In the event of falling wheat prices, farmers (who are basically satisficers not optimizers) recognize that in order to maintain their income level, yield must be increased. To achieve this, farmers can apply more fertilizer per acre of land. This action cannot be continued indefinitely, however, since at some point the cost of the added fertilizer is not offset by the value of the increased yield. Presumably, when farming becomes less profitable, production and input application would both be reduced. In fact, such may not necessarily be the case. Brown (4) suggests, for example, that in capital-intensive agriculture, response to changing profitability in the short run may be small due to the high fixed/variable cost ratio (pg. 16). Producers may need to operate their farm equipment at or near full capacity to make them cost-effective. (Insurance, labor, tax, and depreciation charges are fixed.) In addition, if no alternate use is available, the idled land may degenerate through erosion.

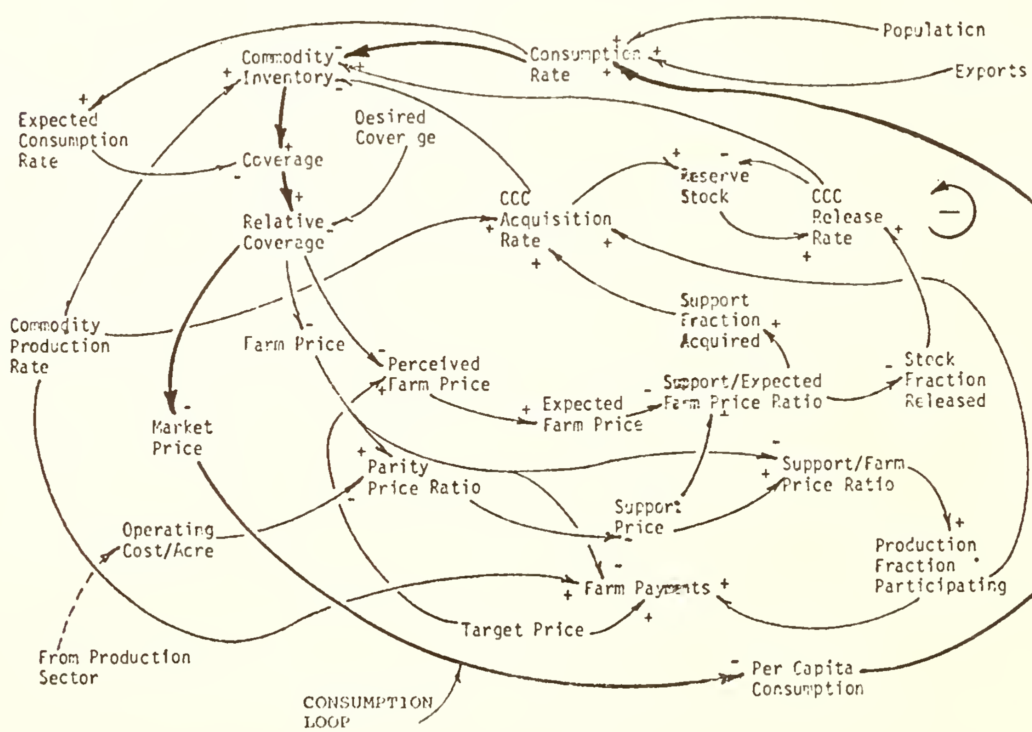
The farmer constantly weighs the fertilizer-application decision (which gives short-term results) against the decision to

CAUSAL LOOP DIAGRAM

Supply Sector



Demand and Farm Program Sectors



increase long-term production capacity (which requires a more lasting commitment of capital and greater risk). When the expected price of wheat rises, all else held constant, wheat farming is more profitable. The farmer then channels a larger fraction of his capital into new land and equipment. He can finance this capacity expansion, partly at least, through reduced fertilizer usage.

The second major feedback loop in the supply sector is the production capacity loop. This loop assumes that if profitability is high, the farm operator will expand production capacity through the acquisition of new farmland and related capital equipment. The critical element in this process is the delay involved in increasing capacity. Time is required for the farmer to plan,secure financing, order new equipment, install new facilities, and till previously idle land. The farmer is perpetually reacting to past trends in market price. By the time new capacity is developed, the market conditions may be entirely different from those which initiated the action. This delay in acquiring new capacity is a major source of cyclic behavior in the wheat system.

Weather quality is assumed to be a stochastic variable which affects the production rate in an random manner with a standard deviation of 10%.

2) In the demand sector, domestic consumption is largely determined by the market price of the commodity. As price rises, consumption tends to decline. Since domestic usage of wheat takes approximately 30-40% of production, exports are by far the most important determinant of total consumption. Export demand, treated as another stochastic variable in the model, fluctuates in the same manner as world production. (These variations are largely due to changing world weather conditions.) There is some evidence that export demand is highly price inelastic (Barr,Hoffman (5)(6)). Importing nations seem to meet their shortfalls regardless of the current price. The Barr-Hoffman model, for example, achieved the closest fit to historical data by not including price in the econometric equation that determines export demand.

3) The farm-program sector represents the activities of the Agricultural Stabilization and Conservation Service. These activities include the administration of the Commodity Credit Corporations' reserve stock, the farm-loan program, and the deficiency-payment program. These programs operate when farm prices are depressed and the target or support prices exceed the

existing market price. The farm programs attempt to stabilize producer incomes and domestic prices, provide a partial means of financing for farmers, provide a measure of insurance against unpredictable weather conditions, and maintain a domestic reserve stock. The CCC sells off its stocks in the open market when prices rise above predetermined levels, and it acquires producer stocks when the market price falls below the established government support price. This process keeps the regulated stocks from entering the open market and attempts to prevent a further depression of price.

The interactions between these model sectors and the delays involved in production planning cause oscillatory behavior (documented by Vaux-(7) and explained by Meadows (8)). In a free-market system, price acts to adjust demand to equal the existing supply. The delays inherent in the production process and the low marginal cost involved in expanding production reduce the effectiveness of price as a regulator. Production is limited only by the farmer's total acreage and existing capital stock. If the producer is operating below full capacity, the marginal cost for expanding production is relatively small.

In the wheat system, there is a delay of approximately one year between a decision to increase production until the new investment contributes to farm output. As previously stated, the high fixed/variable cost ratio provides an incentive to produce at or near full capacity even though farm price may be falling. This incentive tends to increase the length of the production delay by increasing the time needed to respond to changing market conditions.

Besides short-term supply inelasticity, the low elasticity of demand also contributes to instability. Domestically, consumption may be largely determined by custom instead of price when incomes are sufficiently high to discourage reduced consumer expectations.

Supply and demand inelasticities in conjunction with the production delay cause the system to be unstable in the face of unexpected disturbances. In the computer model, the nature of the negative feedback loops (production-capacity and consumption) and the inherent system delays in first perceiving and then reacting to the market conditions, produce cyclic behavior. The cycle generated by the model has a period (length from one peak in production to the next) of approximately four and one half years.

The model's oscillatory behavior is analogous to one which can be derived by the traditional cobweb model. (Samuelson (9)). The cobweb model predicts that a cycle periodicity approximately twice the length of the production delay (Meadows - pp. 11-12). In the computer model constructed for this study, the period is two times the cumulative length of the delays around the entire production-capacity loop.

THE STANDARD RUN

The Standard Run is for reference purposes only, not a most likely prediction of the future. Its' purpose is to portray some of the basic behavioral characteristics of the wheat system.

In this simulation, the author's estimates regarding expected future export demand were incorporated to examine the wheat system over the next 10 years. The 1975 grain sale to the Soviet Union was not included. Exports were assumed to increase by 25 million bushels per year with some random noise superimposed.

There is some debate as to the effectiveness with which technological advances will permit increased agricultural productivity. Some experts believe that the most reasonable assumption is that yield will follow the trendline increases of the past, resulting in an estimated yield-per-acre increase from 35 to approximately 44 bushels per acre between 1975 and 1985.

Other experts doubt that the steady trendline increase in American agricultural productivity will continue. The National Academy of Sciences (10) study on Agricultural Production Efficiency suggests that "a definite leveling off of crop yield response to fertilizer application is in prospect".

As a result, the Standard Run incorporates an assumption between these two extremes. Yield is assumed to rise continually, but not as rapidly as the previous estimate, to 40 bushels per acre by 1985. In effect, the fertilizer application loop was circumvented to prevent diminishing returns to the application of fertilizer between 1976 and 1985.

Weather variations (determined randomly), could reduce production from full capacity in any year. All other variables are determined endogenously by the model.

The Standard Run (Exhibit 6) demonstrates a pronounced cyclic behavior from 1975 through the end of the decade. The record production in 1975 and 1976 permits depleted inventories to be replenished to their 1966 level of 400 million bushels. Price oscillates around $3.80 per bushel as compared to the $1.80 / bushel level of the mid 1960's. Production continues to reach record levels due to the increasing yield trend. Since the cost of farm inputs rose after the 1973 Arab oil embargo, the new $3.80/bushel price level is high enough to offset increased production costs, but not to encourage the development of new production capacity. Therefore, no new land is brought into production, and total acreage under cultivation fluctuates around 64 million acres.

Interestingly, the model exhibits highly visible production-capacity and market-price cycles through the last half of the computer run as compared to the more stable price behavior from 1965 through 1973. The explanation for this change in behavior lies in the fact that the reserve stocks and privately held inventories were at such low levels by 1973, that they lost their ability to buffer the system from unexpected weather and export aberrations. Such behavior is replicated in Exhibit 7 which shows Farm Price over the past seventy-five years. The price behavior was oscillatory until approximately 1940 when the government farm programs and the CCC reserve stock came into existence. From 1940 through 1970, the cycles are still discernable, but the oscillations are considerably attenuated. After 1970, the model suggests that the reserves were sufficiently depleted by the 1972 Soviet grain sale and two subsequently disappointing crop years to cause pronounced price instabilities to re-occur.

Appendix 1 provides a comparison of actual historical data and the computer-model forecasts.

EXHIBIT 6

THE STANDARD RUN

(not including the 1975 Soviet Grain Sale)

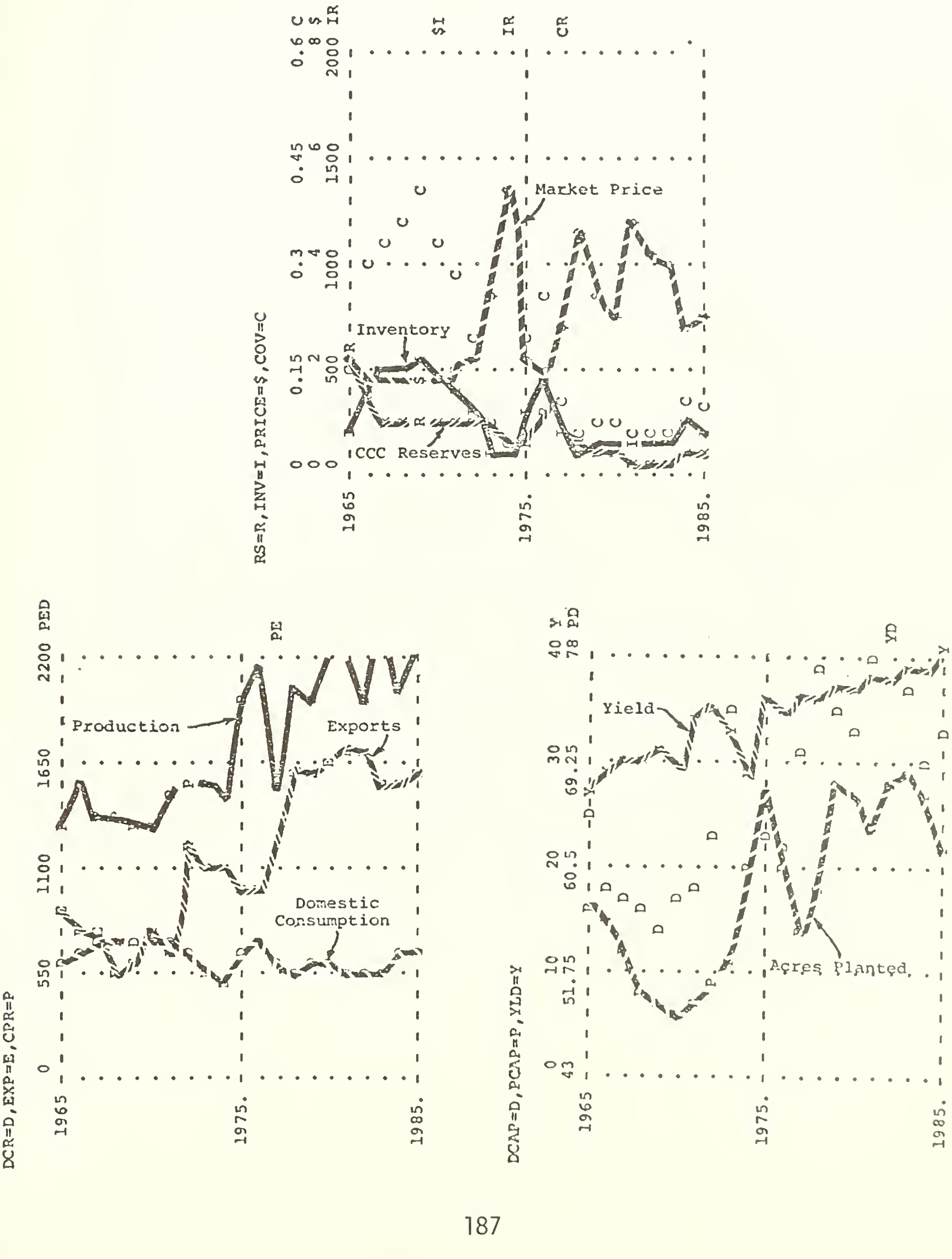
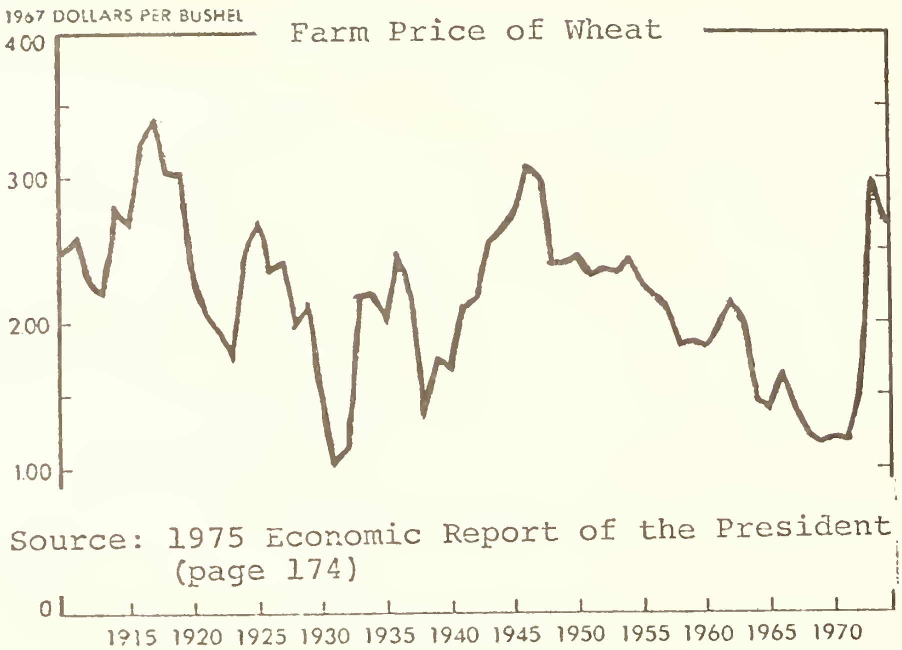


EXHIBIT 7



THE GRAIN SALES

To determine the likely impact of the scheduled 1975 Soviet sale, an additional run has been made with exports increasing by 700 million bushels in 1975 and 1976. All else remains as in the Standard Run. The total export demand for those years was assumed to be 1.35 billion and 1.3 billion bushels respectively. The resulting behavior is shown in Exhibit 8. Surprisingly, the inclusion of large export demand actually reduces the system instability ! Market price eventually assumes a value of $3.80/bushel as in the Standard Run, but not until 1980. Price cycle fluctuations are effectively reduced until inventories become low enough to prevent further buffering. If prices rose inordinately, more farmers would be expected to plant wheat and the acres under cultivation should rise. In the simulation, acreage planted actually drops to 59 million acres by 1977, suggesting that the system has simply stabilized at a higher price, commensurate with higher production costs.

By examining the plots which show production and acres planted (in Exhibit 8), it is clear that the 1975 grain sale comes at a time when production is at the peak of its cycle. (This situation is analogous to that shown in Exhibit 3). Whether or not this result parallels the 1972 Soviet purchase is an interesting question.

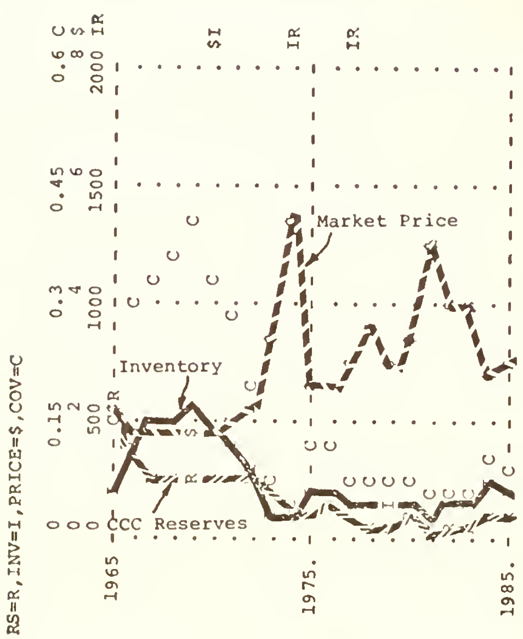
To test what would have happened without the 1972 purchase, a third computer run was made reducing exports by 554 million bushels in 1972 and 1973. The result appears in Exhibit 9. In this case, the grain sale most decidedly had an adverse effect on system stability. Without the sale, price gradually increases to levels observed in the earlier runs. In essence, the 1972 sale depletes stocks to a low level and the disappointing growing seasons in 1973 and 1974 make it difficult for farmers to rebuild inventories even though the high price stimulates production. Price rises to a peak value of $5.80 per bushel. In contrast to the 1975 case, this sale comes at the low point of the production cycle and, as a result, severe oscillations occur. The system is highly vulnerable to shocks when the production cycle is at its low point. When production is low, a disturbance must be absorbed by the reserve stock. Only after the reserve stock is depleted will price rise to stimulate a production expansion. Due to the delays previously described, price could continue to rise for up to two years until the added production capacity contributes to output.

EXHIBIT 8

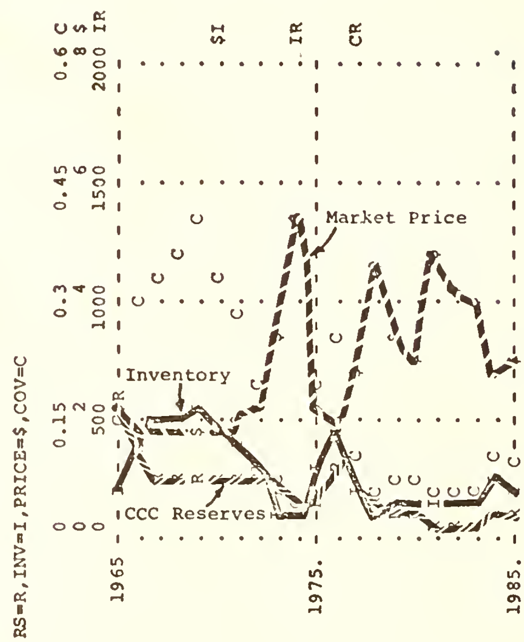
RUN INCLUDING THE 1975 SOVIET GRAIN SALE

(compared with the Standard Run)

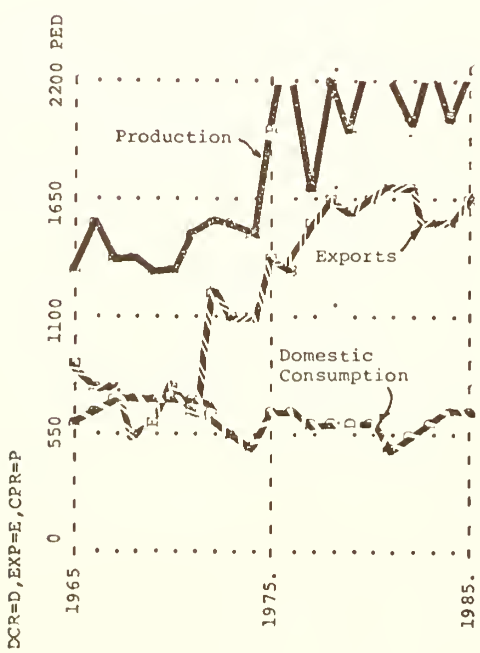
With the 1975 Grain Sale



Without the 1975 Grain Sale
The Standard Run



With the 1975 Grain Sale



With the 1975 Grain Sale

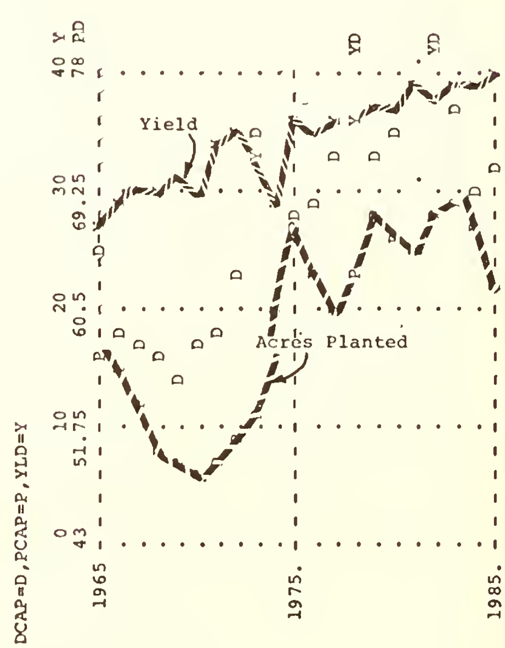
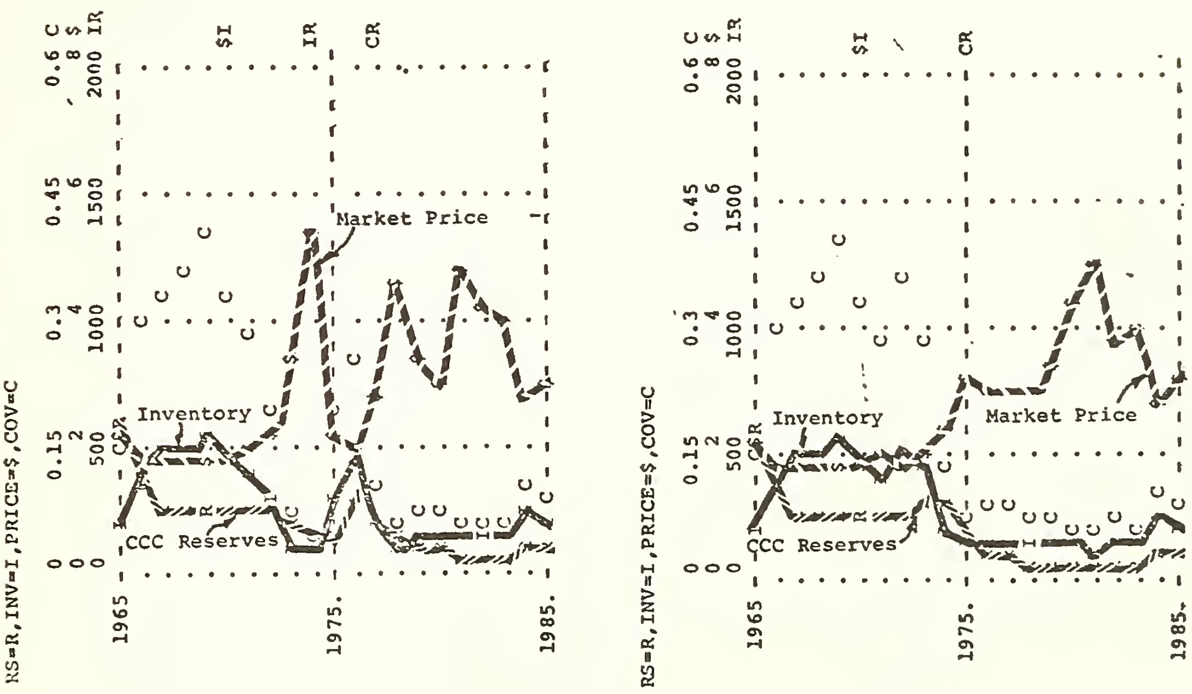


EXHIBIT 9

WITH THE 1972 GRAIN SALE

WITHOUT THE 1972 GRAIN SALE



The preceding observations tend to suggest that the high price levels forecast by the model are not a function of the grain sale per-se, but of forces within the system which determine the profitability of expanding production capacity and the increased demand for exports. If the yield estimates are correct and if this country is not willing to commit itself to continued export controls, then the system will be characteristically unstable through the next decade. This instability will not result from the inability of U.S. farmers to bring more acreage into production, but because the dynamics of the system dictate that farmers acting in their own self interest will reduce production when prices are low. The computer run in Exhibit 6 for example, shows that even though reserves and inventories are replenished by 1976, the low price causes a

decline in acres planted to 55 million acres in 1977. (Wheat farming becomes unprofitable and farmers either go out of business or shift to other more profitable commodities.)

The national policy issues raised by this dilemma are both complex and emotional. Restricting U.S. food exports may have severe global consequences. Government intervention, on the other hand, to increase acres under cultivation and establish a reserve stock, may displease farm groups and lead to an inefficient allocation of resources. It is clear that the concept of timing large grain sales is equally as important as the concept of establishing a reserve stock in the United States. This paper demonstrates that current agricultural policies are inadequate to stabilize the system if high export levels persist. If the 1975 Soviet sale were avoided in order to rebuild CCC reserves to their 1966 levels, the price becomes sufficiently depressed to cause severe production cut-backs and pronounced price-cycles result. Even if a large reserve stock were maintained outside the realm of the commodity markets, so as to prevent a depression of farm prices, it is possible that the markets would discount the price due to the very existance of the reserve stock. If such discounting would occur, it is likely that the price would fall as suggested by the model runs presented in this paper (See exhibit 8) and the stocks would be self-defeating.

A program designed to promote short-term grain-sale pacts at key points in the production cycle may be an effective stabilization policy.

CONCLUDING REMARKS

With respect to the 1975 Soviet grain sale:

1) The behavior of the American wheat system is characteristically cyclical, although the oscillations have, in the past, been significantly reduced by maintaining a suitable buffer stock.

2) The effect of any large grain sale is highly dependent upon when in the production cycle it occurs.

3) Since the 1975 sale comes at the peak of a

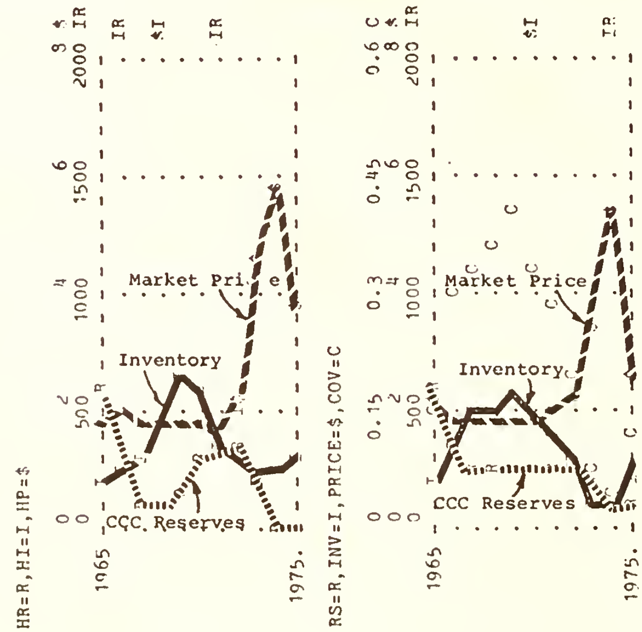
production cycle, the system response will be attenuated and the grain sale is desirable at the present time.

4) A reserve stock program which ignores the timing of future grain exports, may not be capable of producing the intended domestic price-stability.

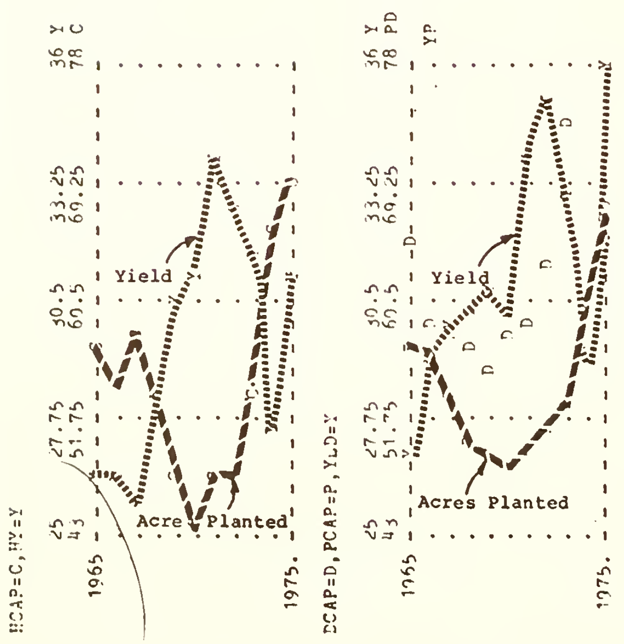
APPENDIX 1

COMPARISON OF HISTORICAL DATA WITH MODEL PREDICTIONS

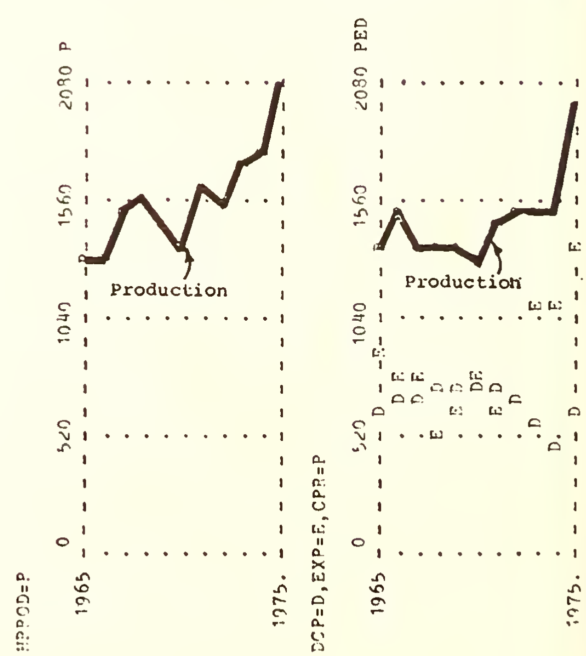
Actual Data   Model Generated Data



Actual Data   Model Generated Data



Actual Data   Model Generated Data



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SHORT BIOGRAPHICAL NOTES ABOUT CONTRIBUTORS

1. "Grain Stocks and Economic Stability: A Policy Perspective"

Dale E. Hathaway was a professor and chairman of the Department of Agricultural Economics at Michigan State University until 1972. He then became program advisor for Agriculture, Asia, and the Pacific, International Division of the Ford Foundation. On August 1, 1975, he became director of the International Food Policy Research Institute, 1776 Massachusetts Avenue, N.W., Washington, D.C. 20036. Dr. Hathaway has a long experience as an advisor on food policy to the U.S. Government and international organizations.

2. "Should Developing National Carry Grain Reserves?"

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David J. Eaton is assistant professor of public policy at the Lyndon B. Johnson School of Public Affairs, the University of Texas at Austin. He is completing his Ph.D. in environmental engineering systems in the Department of Geography and Environmental Engineering of Johns Hopkins University. He has worked with the President's Council on Environmental Quality, the U.S. National Science Foundation, the U.S. Agency for International Development, the International Bank for Reconstruction and Development, and the U.S. Department of Agriculture.

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3. "A Method to Size World Grain Reserves: Initial Results"

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4. "An Optimization Approach to Grain Reserves for Developing Countries"

D. Gale Johnson holds a Ph.D. from Iowa State College. He has taught at Iowa State College and University of Chicago, where he is currently professor of economics and provost of the University. He has published many articles and books, including Forward Prices for Agriculture (1947), World Agriculture in Disarray (1973), and World Food Problems and Prospects (1975).

Daniel Sumner holds a B.S. from California State Polytechnic College and a M.A. from Michigan State University and is a Ph.D. candidate at the University of Chicago.

5. "Reserve Stock Grain Models and the World, 1975-85"

Willard W. Cochrane is currently a professor of agricultural economics and professor of public affairs at the University of Minnesota. He received his Ph.D. in Economics from Harvard University in 1945. He was director of agricultural economics and economic advisor to the Secretary, U.S. Department of Agriculture from January 1961 to June 1964. He has been a professor of agricultural economics at several universities, and was dean of the Office of International Programs at The University of Minnesota. He is an elected fellow of the American Farm Economics Association.

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6. "Grain Reserves and the U.S. Economy: A Policy Perspective"

G.E. Brandow is a professor of agricultural economics at Pennsylvania State University. He has a Ph.D. from Cornell University and specializes in food and agricultural policy. He has worked for governmental agencies and is a past-president and fellow of the American Agricultural Economics Association.

7. "AGRIMOD: A Simulation Model for Analysis of U.S. Food Policies"

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Elizabeth R. Ducot holds a B.A. in physics from Smith College. She is currently a senior systems analyst at Systems Control, Inc. where she specializes in the design of large scale socio-economic systems models suitable for policy analysis.

8. "Grain Reserves for Feed Grains and Wheat in the World Grain Market"

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9. "Farm Programs and Grain Reserves - Simulated Results"

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James W. Richardson is a research associate in the Department of Agricultural Economics, Oklahoma State University. He received his M.S. in agricul-

tural economics from Oklahoma State University in 1973 and is presently working toward his Ph.D. He has contributed to the development of POLYSIM.

10. "Analysis of a Grain Reserve Plan"

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11. "Grain Sales and Production Cycles - A Computer Simulation Study"

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